1992 — 1993 REPORT

Institute of Freshwater Ecology

Natural Environment Research Council

Foreword

During the year the Institute of Freshwater Ecology has been subjected to a quinquennial Science Management Audit. I am delighted that this review has endorsed the high quality of the science and its relevance to environmental issues and the water industry. The issue of water quality is attaining increasing prominence, and this is only one of the many areas in which IFE's activities are of key importance.

I succeeded Professor Bernard Tinker as NERC Director of Terrestrial and Freshwater Sciences towards the end of the year under report and I should first like to acknowledge the skill and wisdom that he has shown in steering TFSD through some difficult times. I have inherited a strong science and management base on which to build. I have spent much of my first few months at NERC in seeing at first-hand the research within the Directorate. This has been immensely enjoyable and I am greatly impressed by the quality and variety of the research whether undertaken on the Science Budget or for the wide range of customer organisations.

A strong feature of the Directorate's research is the degree of multidisciplinarity, interdisciplinarity and collaboration. This collaboration is strong not only within the Directorate's own establishments (the Institute of Freshwater Ecology, the Institute of Hydrology, the Institute of Terrestrial Ecology, the Institute of Virology and Environmental Microbiology, the Centre for Population Biology (Imperial College), the Unit of Behavioural Ecology (Oxford University), the Unit of Comparative Plant Ecology (Sheffield University)) but also with other Institutes and Universities. This collaboration is strongly encouraged through Community Programmes such as TIGER (Terrestrial Initiative in Global Environment Research).

Professor C Arme
Director of Terrestrial and Freshwater Sciences
Natural Environment Research Council

Front Cover Illustration:
Thermal line scan over the River Severn, between Leighton and Buildwas Park, Shropshire, showing remotely-sensed water-surface temperatures which range between 16.6°C (dark blue) and 18.5°C (bright red). The differences in temperature, which have been verified by ground truthing, attest to the complex velocity structure in river channels: weakly- or non-flowing 'dead zones' retain more solar heat income than do the more dynamic areas, away from the sheltered banks and point bars. Flow is from bottom to top. Surveyed 10 July 1991. Imagery is the property of NERC.

Report of the Institute of Freshwater Ecology 1992/1993

Natural Environment Research Council

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Director's introduction

Professor J Gwynfryn Jones
Director

The presentation of the Annual Report provides the Director with the opportunity to summarise the achievements of each Institute. The Terrestrial and Freshwater Sciences Directorate of the NERC represents an extremely "broad church" with a range of research programmes that will not be found elsewhere in the Council. The Institute of Freshwater Ecology reflects that breadth and, therefore, my first task was to determine whether we had achieved the objectives we had set ourselves. A brief examination of the Contents pages of this Report demonstrates unequivocally, that we have been successful, but leaves two questions unanswered. What was the cost of this effort, and how long can it be sustained?

The *raison d'etre* of an Institute is that it is well placed to conduct long-term and truly multidisciplinary research. Our programme ranges from providing a service to the scientific community (through, for example, the Culture Collection of Algae and Protozoa) to maintenance of our long term research programmes on fish populations, including those species which are recognised to be endangered. Within these programmes we also work at the sub-cellular level (bacterial endosymbionts of protozoa) through to whole ecosystem studies (the use of remote sensing techniques to assess the health of lakes and reservoirs) and to community studies of freshwater invertebrates which are of ever increasing importance in providing advice on the state of our rivers. Similarly, our chemical research, which incorporates a significant interaction with hydrologists, ranges from the detailed study of species interaction through to the production of predictive models of soil/water interactions.

The eight major research projects of the Institute have, therefore, achieved their objectives. The results of the programme on the Management of Lakes and Reservoirs are in constant demand particularly for the production of active management models for still waters. These combine effectively with the programme devoted to assessment and prediction of change which has a particular role to play with regard to Scottish waters. Similarly the research thrust on rivers (Ecology of Large Lowland Rivers, Land-River Interactions and River Ecosystem Processes) have combined to produced both high quality research and invaluable advice to the Nation's decision makers. The more subject-orientated programmes (Microbes in the Aquatic Environment, Fish Population Dynamics and Management and Physico-Chemical Processes in Catchments) have combined a quality of expertise which has been recognised both by the academic community and customer department alike.

What, then, are the main problems facing the Institute? We have come through a period when long-term research (monitoring) was considered to be unfashionable – yet we now recognise the value of long term data sets as we grapple with the problems of global change. These programmes must be underpinned by research into the mechanisms which underlie the changes we see at population, community and ecosystem level. There can be no doubt that the Institute has struggled to provide adequate finance for long-term research and to persuade appropriate funding bodies that true understanding of the events observed at ecosystem level can only be achieved through interaction with more specific (eg genetics eco-physiological) research. Our community of scientists has remained intact, admirably supported by all those whose names do not, necessarily, appear on scientific papers and reports. What appears as a widespread programme, provides the UK with an unparalleled body of expertise which can respond to the demands of the future.

The cost of maintaining this body of knowledge has been met in full by the staff of the Institute. We have undertaken commercial work, in certain sectors, which had little scientific content. This has placed considerable pressures on individuals who realised that such work would ensure the survival of the whole organisation.

There is a limit, however, to which any organisation can be pushed to solve immediate problems, without due regard to assessment of those questions which will face future generations. I believe that we have reached that limit, but at a time when I detect a change of emphasis, and an increased awareness of global environmental problems.

I am moving on to new duties, and therefore this is my last Annual Report as Director. I have avoided naming individuals in my summary, but I would like to take this opportunity to thank all the staff who have made such a marvellous contribution to the future of the Institute, and those within NERC who have responded to our vision of this future.

Management of lakes and reservoirs

Progress

Previous project reports under this heading have attempted to reflect the ongoing interest in the 'ecosystem health' of particular lakes and reservoirs, as well as to give some indication of our work in evolving attitudes and strategies for controlling, managing and protecting water quality at particular sites. Besides being practically achievable, such methods must be ecologically based. In prescribing lake therapies, we need to recognise the ecology of the system to be controlled and to predict its response – and rate of response – to a given strategy of management therapy.

The year ended has seen the completion of two contracts for strategic water-quality models. In addition, management advice has been prepared for several other customers, one for lakes, four for reservoir/resource upgradings (one overseas) and one for the design of a new reservoir. We have also sought to enhance the physiological-ecological basis for management of appropriate systems by intermittent destratification and/or by the application of biomanipulation theory. A further contract has been undertaken which is intended to lead to models of internal fluxes of nutrients and their capacity to postpone smooth and rapid recoveries in response to reduced external loads of phosphorus. We have even found ways to support innovative studies in light-harvesting physiology in actively-mixed algal populations and in the exchange capacities of sediment. These have intermeshed closely with the computer modelling work, leading to palpable improvements in authenticity of existing models.

This overview may assist the reader to absorb the different aspects of the Group's varied programme in water quality management theory and practice and to relate them to the overall objectives of the project.

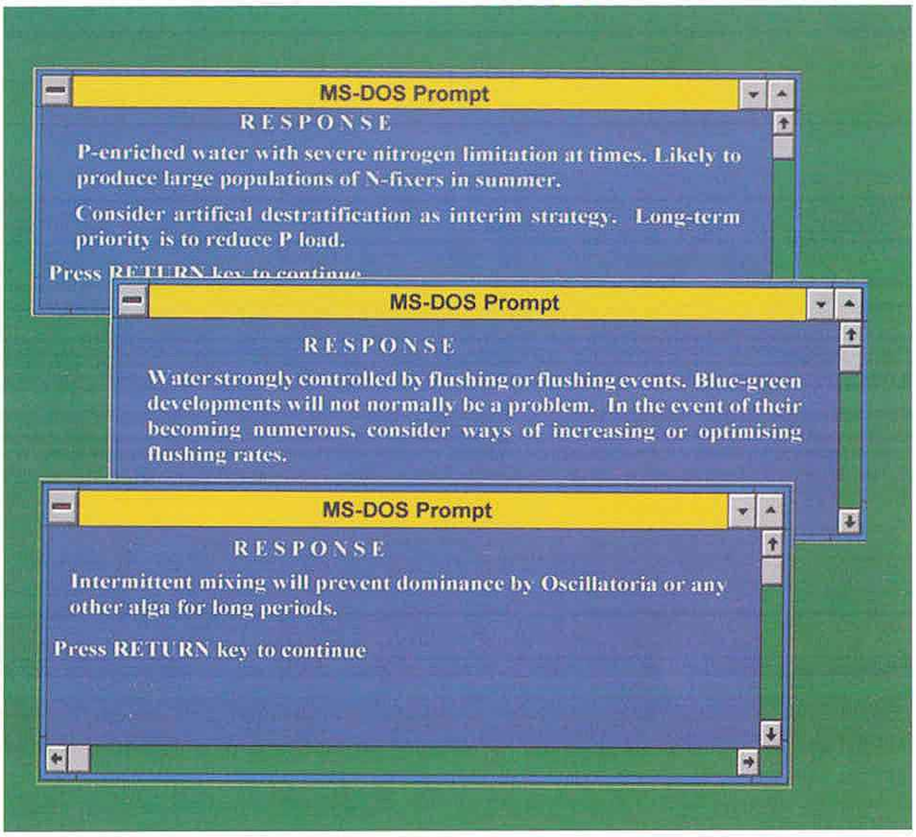


Figure 1. PACGAP responses to information provided.

Choosing Therapies

In diagnosing the root cause and prescribing the most effective treatment for perceived water quality difficulties in a given system, it is valuable to test, from existing databases, for its maximum sensitivity. For instance, if it can be shown that the phosphorus supply is saturating but the maximal algal crops develop only in warm summers, artificial destratification may prove a better management option than tackling the phosphorus loads. Last year's report indicated a 'decision tree' approach to determining the potentially most successful of some half-a-dozen treatment options for the body of water in question. The choices in the matrix were qualitative. However, by turning each question into a quantitative crop-bearing prediction, it is possible to select the critical choice. In our model, PACGAP, the calculations and comparisons are executed in an instant and a suggested course of action – one of 24 – is chosen from a library of responses. The model also permits re-runs with adjusted components (less phosphorus or nitrate, more mixing, more flushing etc) which can be tried until a new response is given. This then gives the measure of remedial action that may be required to bring about the desired improvement and, incidentally, to identify the most sensitive control. PACGAP is not designed to assert a treatment, merely to suggest where further investigations are most usefully placed.

Simulating populations

Progress has also been made in simulating growth of up to eight individual species in water columns subject to warming and cooling across their surfaces (real data), wind action, hydraulic exchanges and nutrient loads (also real data). At each time-step, the new population is calculated by its movements, either by physical mixing or by its own intrinsic movements, accounted and the physical/chemical characters of each 10-cm water layer are recalculated. The outcome may be summated in terms of aggregate mass and presented for part or all of the water column. The illustration shows the result of an attempt to reproduce the fluctuations in lake chlorophyll concentration in the upper 5m of Blelham Tarn during 1974, (for which year a full set of determinations of actual nutrient loads was available). The pattern is clearly well simulated – the outstanding difficulty was to reproduce the encystment and rapid elimination of *Ceratium* in autumn – nobody has instructed the model that algae don't either just die, get eaten or are washed away.

This model (PROTEC 2) is perhaps more academic than applied – though it does suggest that we do understand how algae actually behave in the wild. Yet it is amenable to the testing of the impact of quantified environmental alterations wrought through more mixing, less nutrient, enhanced grazing and so on.

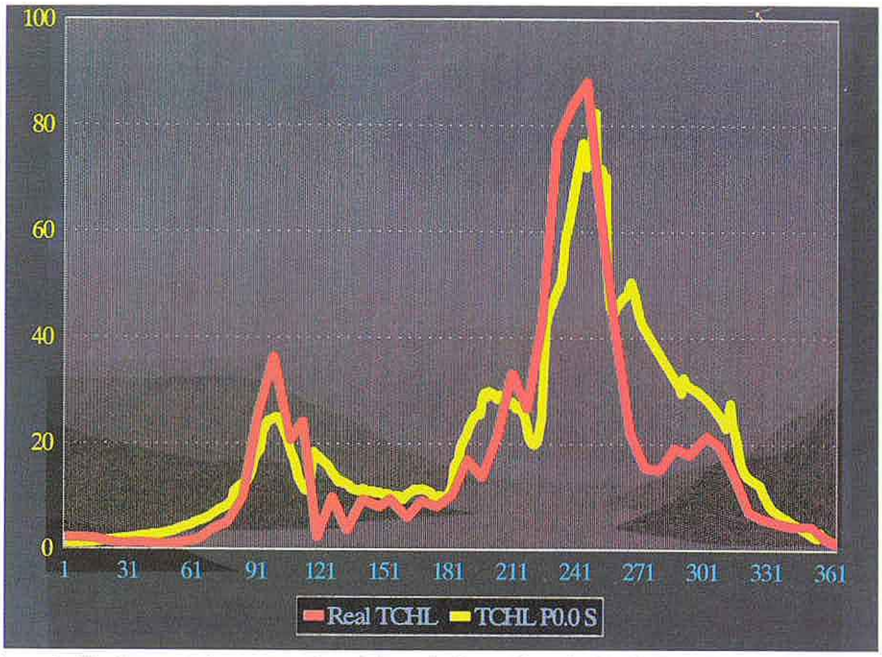


Figure 2. The integrated concentration of phytoplankton chlorophyll in Blelham Tarn, as predicted by PROTEC 2 in respect of the weather - and nutrient - loading conditions determined in 1974, compared to the values observed during that year.

Understanding fluxes

Immediate options for the future would include attempting to simulate other processes: carbon export to the sediment, oxidative demand, redox, metal solution etc. However, the customer-led priority is to model the transformations in the compartment beneath the water column, with respect to recruitment of cell components, phosphorus fractions and their subsequent mobility. Modelling of the water column has identified a consistent under estimation of the phosphorus available to phytoplankton based only upon the external loads, and that the anomaly increases in shallow waters. The Group is actively investigating how lakes turn over organismic P and the role of the sediments in mediating the true fluxes.

Understanding algae

PROTEC 2 and, to a lesser extent, PACGAP contain species-specific weightings based upon careful analyses of their growth rate responses to temperature and diminishing light doses in deep-mixed columns, which conform to description by regressions. Although these conform also to the known capacities of certain of the species to adapt to extreme conditions, not all the processes in all the species have been investigated experimentally. We see it as an integral part of our developing skills in pelagic management to be able to account for, and predict, the ways in which some species wind-up their light-capturing attributes so much more successfully than others, invest in additional photosynthetic pigment and supplement their spectral cover with accessory pigments. Closely related are the abilities to take up and store nutrients in excess of immediate requirements – these tell us something of the ability to predict growth rates when consumption begins to outstrip supply. An improved knowledge of the mechanisms of these behaviours also improves our ability to simulate and predict them.

The Group looks forward to maintaining its momentum in pursuing these simultaneous and mutually-supportive goals of mechanistic appreciation and modelling ability. It believes that its progress scores against the ideals both of satisfying scientific curiosity and of developing practical skills for protecting environmental quality.

Ecology of large lowland rivers

The ecology of juvenile coarse fish in the River Great Ouse

Introduction

Analysis of the age-structure of individual coarse (= non-salmonid) fish populations often shows a dominance by individuals that were spawned in a small number of years, whereas progeny from other spawnings are poorly represented. Past studies at the IFE River Laboratory have shown that strong year-classes occur in years when the initial growth rate of the newly-hatched fish larvae is high. As fish are poikilothermic, these fast growth rates are usually associated with above average water temperatures. The results of aquarium studies support the claim that, under such conditions, more fish survive their first few weeks of life when they are vulnerable to predation by such aquatic invertebrates as Odonata nymphs and Coleoptera adults and larvae. As most female coarse fish lay several thousand eggs each year, just a small increase in the percentage survival of newly-hatched larvae will result in a large increase in the absolute number of one year old recruits.

However, other studies at the IFE River Laboratory have revealed that water temperature differences explain only c. 65% of the year to year variation in the growth rate of 0 group dace. Water temperature also accounts for only part of the variance in year-class strength (YCS), values ranging from 44.3% for chub to 69% for dace. Determination of the importance of the other factors influencing growth and recruitment of juvenile cyprinid fishes has been the basic objective of recent studies in the River Great Ouse, including the role played by anthropogenic disturbances associated with land drainage, flood control and navigation.

Macro and Micro-distribution of 0 group fish

In a survey of 44 sites along the Great Ouse (Figure 3) in 1989, 964 (35%) of the total catch of 0 group fish were roach and 831 (30%) were minnow; none of the other 17 species contributed more than 10% to the total. The survey was carried out in late summer using a Random Point Sampling technique by electro-fishing. The results, which were confirmed by further surveys in 1990 and 1991, showed clearly that some species (e.g. roach) were ubiquitous, whereas others (e.g. common bream, silver bream) had a much more restricted distribution (Figure 4). The minnow was abundant only in the sites upstream of Great Barford (site 29).

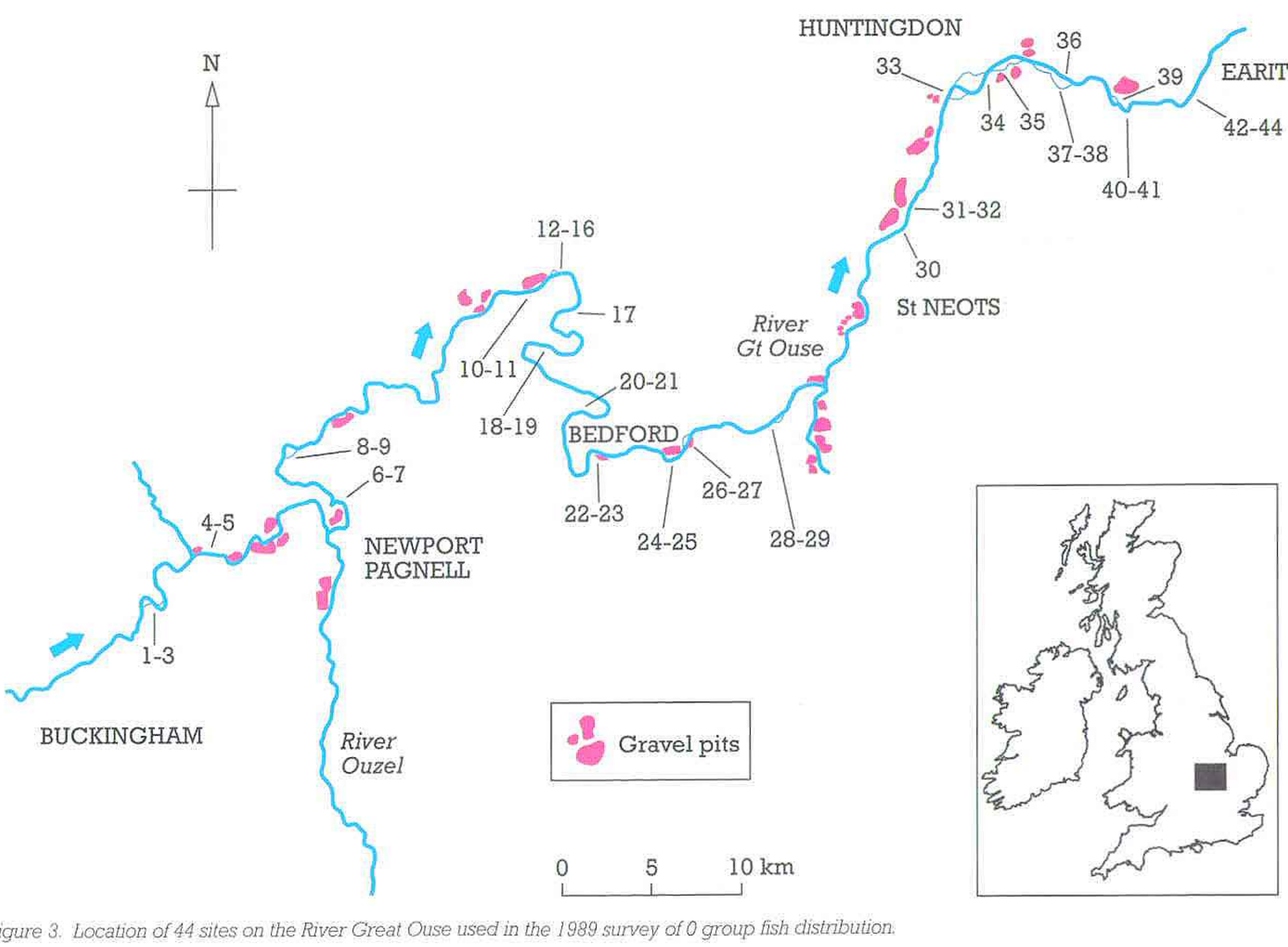


Figure 3. Location of 44 sites on the River Great Ouse used in the 1989 survey of 0 group fish distribution.

As the summer flows through the period of study were very low (because of the drought), it is reasonable to assume that the degree of downstream displacement or drift of fish larvae was low. Hence, the pattern of fish larval distribution was a reflection of the distribution of spawning sites.

On a finer scale, in each of the 1989-1991 surveys, a series of environmental attributes was recorded with each Random Point Sample, in order to identify those that influenced the micro-distribution of 0 group fish. Canonical correspondence analysis showed that habitats characterized by shallow depth, narrow channel width, the presence of riffles and runs, and large substratum particle size were preferred by minnow and young dace. Young chub and gudgeon preferred deeper, wider channels with moderate currents and smaller substratum particles.

Changes in micro-habitat preference occurred as the larvae grew in size. Thus, once roach larvae became free-swimming, they were associated with shallow depths, slow current speeds, aquatic vegetation and woody debris. After a few weeks when they were able to swim more actively, they were found in more open areas of water with low current speeds, a silty substratum and depths between 0.2 and 0.5 m. Here they were often found associated with 0 group perch (Figure 5).

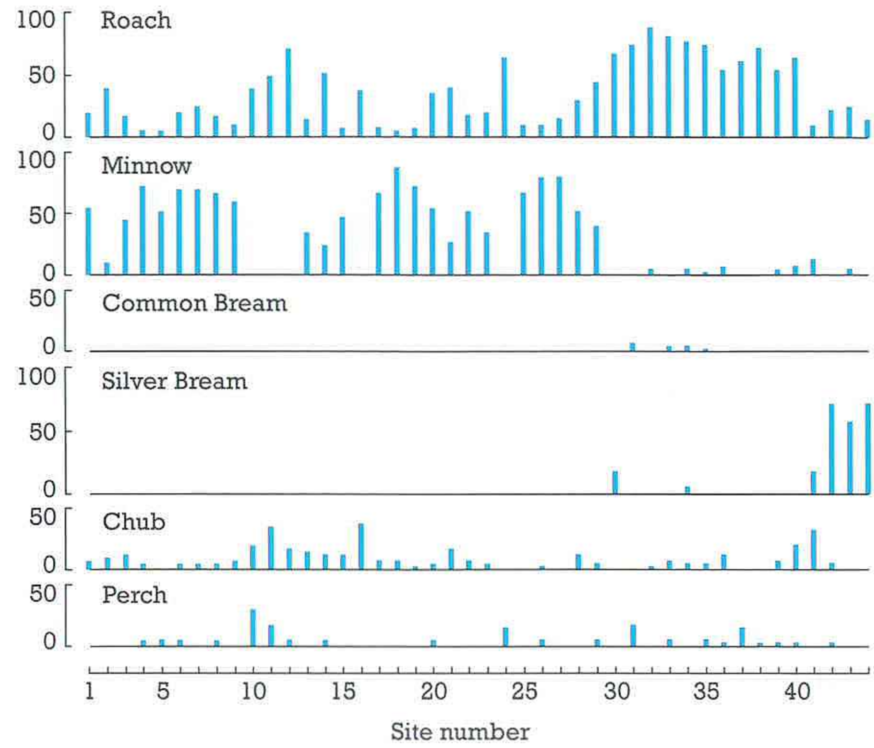


Figure 4. Relative abundance of 0 group fish at 44 sites on the River Great Ouse in August 1989.

Figure 5. Fry sampling.

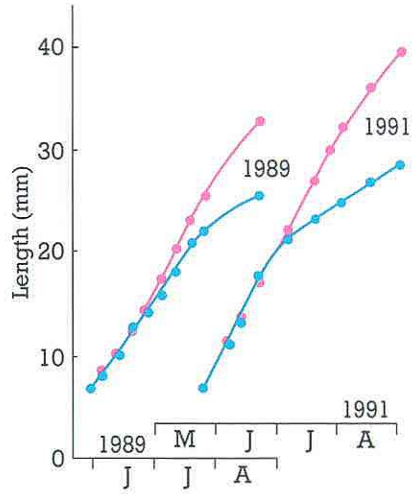


Figure 6. Observed and theoretical growth curves for 0 group roach in the River Great Ouse; theoretical curves are based on known growth responses of roach to water temperature.

Growth of 0 group roach

The seasonal growth pattern of 0 group roach was examined in 1989 and 1991 and compared with the theoretical growth curve predicted from a model relating growth increments to initial size and ambient water temperature (Figure 6).

In both years the observed rates of growth agreed with those predicted from the model during the first six weeks (approximately) of larval life, which suggests that food was not a limiting factor for growth during this period. However, from late June onwards, the observed growth rate fell behind the predicted rate. It was during this period that the young roach switched from a largely invertebrate diet (Rotifera, Cladocera, Chironomidae larvae, Copepoda etc.) to one dominated by the detrital *aufwuchs* found on submerged plant surfaces, especially water lily *Nuphar* leaves (Figure 7). In contrast, common bream larvae continued with an invertebrate diet and never utilized the *aufwuchs*. The roach x common bream hybrids had a similar diet to the roach.

Striking year to year variations have been observed in the initial diets of newly-hatched roach. In 1989 the hatching date of roach larvae coincided with a bloom of *Stephanodiscus* diatoms in the river. These diatoms formed the initial exogenous food items of the roach, followed almost immediately by rotifers. In contrast, in 1990, few *Stephanodiscus* were available in the water column when the roach hatched, and rotifers formed their initial exogenous prey. Moreover, in 1990, there was a greater abundance of Cladocera than in 1989 and this difference is reflected in the average numbers found in roach guts in the two years (Figure 7).

It is interesting to note that, though the mean sizes of roach larvae at the end of the 1989 and 1990 summers were approximately the same, the growth trajectories during the summer were very different. During the first month after hatching, both year-classes grew to a mean length of 15 mm in 150 degree days (calculated as the number of degree days over 12°C, which is the approximate lower temperature threshold for the growth of most coarse fish). Subsequent increase in length to c. 28 mm took 43 days in each year, but this represented 430 degree days in 1989 and 210 degree days in 1990. Conversely, growth from 28 mm to c. 33 mm took 19 days (130 degree days) in 1989 and 33 days (250 degree days) in 1990.

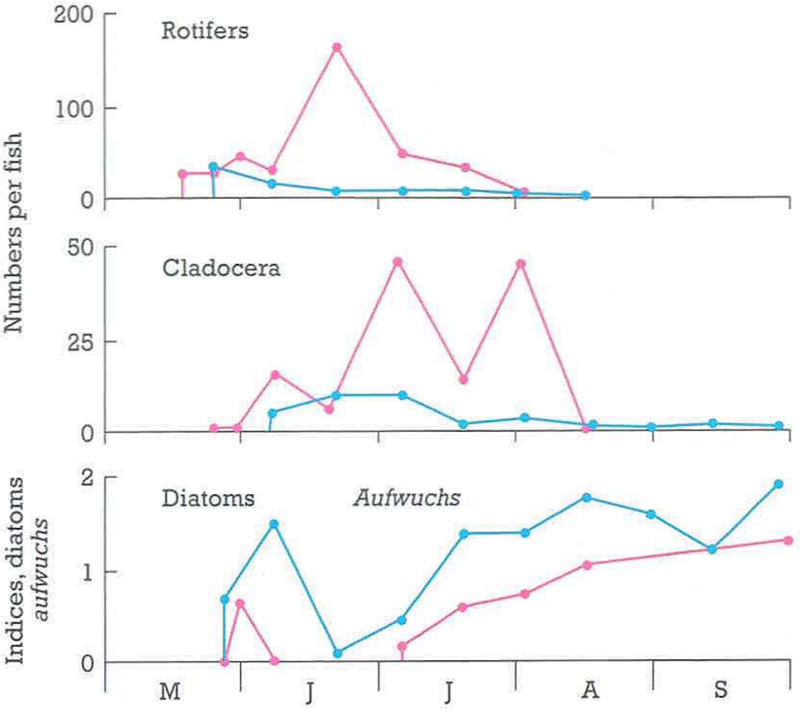


Figure 7. Seasonal changes in the Rotifera, Cladocera, Diatom and Aufwuchs *components of 0 group roach diets in 1989 and 1990. Rotifera and Cladocera values = numbers of prey/fish; diatom and* Aufwuchs *values are indices, from 0 (absent) to 3 (full).*

These data indicate that factors other than water temperature influence growth rates, the available evidence suggesting that quantitative and qualitative differences in available food items are important. Analysis of the diets of cyprinid species other than roach, and for years other than 1989 and 1990, although not completed, strengthen this conclusion and point to pronounced interspecific variation and to intraspecific changes related to ontogeny.

There has been much interest in recent years in the role of the flood plain in the maintenance of a diverse fish community. Most U.K. rivers have lost much of their natural flood plain and river flows are generally confined to a single river channel. Flood events are few, and backwater areas have been much reduced. The present structure of the River Great Ouse system includes flood banks, automatically operated sluices, regular weed-cutting and the presence of navigation locks. Although many off-river backwaters have been lost, the increase in the pleasure boat industry has led to the development of many marinas, either large ones that cater for many boats or small 'lay-bys' for individual boats. These areas provide important refugia for 0 group and older fish, especially during the winter months when the river is in flood. Additional backwaters could be provided by connecting the river to some of the flooded gravel pits that occur along the river. (Figure 3)

During the summer, many roach larvae migrate from the main river spawning areas and riparian nursery zones into the marinas. Plankton samples and diet studies show that these areas provide different food resources for fish from those provided in the main river channel. In marinas, 0 group roach do not switch to an *aufwuchs* diet in late June, but maintain a largely zooplankton diet, occasionally supplemented by rotifers. Moreover, identification of the Cladocera has shown that mostly planktonic Cladocera are eaten, especially *Bosmina* but also *Daphnia* and *Ceriodaphnia*. These taxa are found less frequently in the main river channel, and the dominant Cladocera are those associated with plant surfaces (e.g. *Chydorus, Alona, Pleuroxus* and others). This difference is reflected in the diets of 0 group roach and other species.

Conclusions

As expected, summer water temperatures have a direct influence of the growth rates of 0 group cyprinid fishes in the River Great Ouse, but the effects are confounded by year to year variations in food supply. Where zooplankton is sufficiently abundant (e.g.in marinas), it forms a major diet component of roach larvae. However, in the main river channel the roach larvae switch to a predominantly detritus food resource, whereas the common bream continue with a carnivorous diet. (Figure 8)

Figure 8. Seine net catch - River Great Ouse.

Seasonal variations in the water temperature and food availability determine the trajectory of the growth curves of 0 group fish, and hence the survival rates and subsequent YCS of particular cohorts. Future models predicting year class strengths need to include both these variables; water temperature alone may not provide accurate predictions.

Land-river interactions

Introduction

This project attracts a wide range of commissions and this year we feature three different projects funded by customers. They include i) a 6 year project initially sponsored by the Nature Conservancy Council (more recently by Scottish Natural Heritage) on invertebrate survey and classification of rivers for nature conservation; ii) the quality audit of biological samples collected by a number of agencies throughout the UK for use in the 1990 River Quality Survey and iii) a long-term project commissioned by the National Rivers Authority (Northumbria Region) to examine the effect of a barrage on the coarse fish of the River Tees.

Invertebrate survey for nature conservation

It is essential that reliable scientific data on the flora and fauna of rivers in Great Britain are available to the statutory nature conservation bodies to enable them to make an informed selection of rivers for nature conservation, and in particular for notification as Sites of Special Scientific Interest (SSSIs).

Figure 9. Timed pond-net sample from Gordale Beck.

In the early 1980s the NCC published a classification of river types based on the occurrence of macrophytes and from 1986 onwards the FBA (now IFE) was contracted to undertake surveys of the invertebrate assemblages on river systems for which the NCC required data. RIVPACS - compatible samples (Figure 9) were taken in each of spring, summer and autumn over the next 6 years and many different river types were examined throughout Great Britain. Because the same method of sampling was used in this survey and also for RIVPACS (River Invertebrate Prediction and Classification System) the IFE were able to provide valuable information on the fauna of any given site sampled in relation to all other sites in the GB data-set.

Initially, sites were classified to a RIVPACS group using the invertebrate fauna. Once all sites with invertebrate data were classified it was possible to determine whether some river types were poorly represented or absent from the current listing of SSSIs. In considering the fauna of individual sites, the IFE provided information on species richness and also on the occurrence of threatened, rare or infrequent taxa. Species richness was presented in terms of the number of taxa recorded after the standard sampling procedure and could be viewed in relation to the richness observed at sites with similar environmental features. The contribution of the different major taxonomic groups to total site richness was also given.

Within Great Britain, threatened species are listed in the British Red Data Books and rare species are flagged using the 'Nationally Notable' categories originally established by the NCC. For sites examined by the IFE, attention was drawn to species with RDB or Notable status. In addition, for some taxonomic groups where these designations were not yet established, the IFE provided information on the frequency of occurrence of particular running-water taxa within the comprehensive GB data-set.

Quality audit of biological samples

Auditing of the performance of each biologist in the processing of macro-invertebrate samples was initiated as part of the 1990 River Quality Survey (RQS). The survey was undertaken by the National Rivers Authority (NRA) in England and Wales, the River Purification Boards (RPBs) sampled in Scotland and the Department of Economic Development (DED) undertook the work in Northern Ireland. A total of 8,796 sites were surveyed, the majority of which were sampled in spring, summer and autumn.

The 1990 RQS was the first time that RIVPACS was used for the biological component of the survey. Predictions of the fauna to be expected at each individual site in the absence of environmental stress were generated by the RIVPACS software using environmental features for each site. In addition, standard collection procedures were used to acquire the RIVPACS-compatible invertebrate samples. After sorting and identification to BMWP (Biological Monitoring Working Party) family level, the observed fauna at a given site was compared with the target fauna predicted for the same site to determine whether it differed from expectation.

Clearly, the sorting and identification phase of this process is critical and in view of the number of NRA, RPB and DED staff involved, they made the decision to have an independent quality control exercise to promote a consistently high level of reliability. IFE was selected to undertake the audit because the Institute had considerable expertise in the processing of biological samples from sites throughout Great Britain.

Once the samples had been sorted and identified within a given region, they were sent to the IFE River Laboratory where a subset was selected for audit. Out of a total of ~23,000 samples received from the UK, approximately 700 were selected. The procedure for sample selection ensured that all the regional biologists were tested and that they had no means of knowing in advance which of their samples would be audited. Sample selection was weighted towards the spring samples to give early feedback on problems of sorting/identification.
The samples presented for auditing consisted of the following elements. First, a data sheet giving a list of the BMWP families found in the sample. Second, representatives of all these taxa within a vial. Third, the remainder of the original sample in preservative.

The IFE audit of each sample proceeded as follows. The original sample was resorted and all BMWP families were listed. The families within the vial were identified and listed. The listing of families given on the data sheet was compared with those found by IFE in the vial. Finally, a comparison was made between the listing of families on the data sheet and those found by IFE in the sample. In this way it was possible to check both accuracy in sorting and in identification and to provide, on a standard report form, a list of 'gains' or 'losses'. In the case of 'gains' the new family representative was identified to species, where possible, in order to provide a firm basis for avoiding repetitive errors.

In view of the value of the 1990 audit exercise, the various agencies have continued to submit samples to the IFE for audit from their routine biological monitoring programmes in 1991 and subsequent years.

The effect of a barrage on the coarse fish of the River Tees

In 1993 the construction of a barrage will begin at Stockton-on-Tees to impound water in the river and prevent saline intrusion. This is part of the general improvement in amenities in the region of the lower Tees being carried out by the Tees Development Corporation (TDC). At present with a mean spring tidal range of 5 metres, there are unsightly mudbanks for much of the time and most of the 26 km of river affected actually flows upstream during the flooding tide. The average daily flow is 18.4 cumecs and this can rise to 150 cumecs in spate conditions. Coarse fish are limited in their downstream range by the salinity but after construction of the barrage all areas will be habitable. The flow will be very low except during spate conditions when the gates on the barrage will be opened.

There is concern that the coarse fishery which at present is based on dace, with lower numbers of roach and chub, will deteriorate and that the species expected to thrive, roach and bream, will have limited habitat or insufficiently high temperatures for spawning and fry survival. Loss of fish, especially fry, is expected to be high due to the high flows when the flood gates are opened.

A mitigation scheme has been agreed between the NRA and the TDC. This involves the construction of off-stream lakes and bank scalloping to increase the shallow areas for spawning and shelter.

The IFE has been commissioned by the NRA (Northumbrian Region) to survey the fish stocks of the Tees in the area to be affected by the barrage. This seven year project will assess the status of the stocks before construction of the barrage, determine changes in the species composition after construction and assess the mitigation scheme.

Figure 10. Electrofishing using a boom-boat.

A base line survey was conducted in June 1991. It is very difficult to sample fish in large rivers and in this case the recently developed method of electrofishing using a boom boat was employed (Figure 10). This method was successfully used by the IFE in a fish survey of the Hampshire Avon. During this first Tees survey over 1600 fish of 14 species were caught, measured and returned to the river. Dace accounted for two thirds of the fish, with roach and chub being the only other common species of angling importance.

A further survey in September was undertaken to obtain information on the age structure and length-weight relationship of each species. This information will be collected annually and used to detect changes in the population caused by the construction of the barrage.

IFE are also undertaking an annual survey of the fry which will give the first indication of any future change in the species composition of the population. Four main spawning areas for dace have been identified from these fry surveys. Two are within the area expected to be affected by the barrage, but fish from the two sites further upstream may migrate down to the main angling areas. Dace are known to be very mobile and a study is planned for 1993 to mark fish from these upstream areas and use angling matches and the electrofishing survey to recover a proportion of these fish to determine their movement.

In addition to the work on fish stocks, temperature at four sites on the river is being continuously monitored to determine whether the natural temperature regime of the river is altered significantly post barrage. At present the temperature of the Tees in summer is higher than that of the R. Frome, a southern chalkstream, and growth of the fish is good. The temperature study will indicate whether the deeper water post barrage is colder and whether more shallow areas, which are warmer in the summer months, will be needed to produce good growth of the fish.

Despite the problems of sampling a tidally influenced large river, high numbers of fish have been caught and preliminary results from the first two years of the project show that there is a good head of healthy coarse fish in the lower Tees. The information collected has given a sound baseline with which to assess the effects of the barrage on coarse fish.

Microbes in the aquatic environment

Microbial diversity

Current interest in the species diversity of microbial communities has grown out of the realisation that, a) we often have little idea of the number of different organisms living in microbial communities, b) it is often difficult to differentiate between different species of microbes, especially bacteria, and c) there has recently been rapid development of the molecular methods used for analysing (and especially sequencing) the genotypes of microorganisms. In most cases these methods are designed to illuminate qualitative differences in some key molecule – usually the sequence of bases in the small sub-unit of ribosomal RNA.

Sequencing of rRNA genes in bacteria has provided fundamental insight into the phylogeny of bacteria, but with respect to identifying organisms in a microbial community there are as yet no simple methods to calibrate differences in the sequence of nucleotides in rRNA with our current ideas of what constitutes a (phenotypic) species. Thus it is very difficult to compare phenotype with genotype.

There is however one group of microorganisms which may provide an exception. The ciliated protozoa show a rich morphological variety, and there exist precise yet simple methods for resolving the patterns of their species-specific infraciliature. It is also possible to sequence their rRNA, so in theory it should be possible to compare phenotypic species with the genotypes recovered from natural communities.

We have recently begun to analyse and compare genotypic and phenotypic diversity in microbial communities. The first results have come from phenotypic diversity – from two microbial communites in Spain.

We looked at two relatively small habitats: a 10 ml water sample from the anoxic hypolimnion of a sulphide-rich solution lake; and $1m^2$ of homogeneous sandy sediment in the Rio Duratón. The anoxic water sample contained fourteen species of ciliates, all of which were confirmed to be anaerobic. The surprising finding was that seven of these had not previously been described i.e. half of the species in this single water sample were new species. The fourteen species belong to all six orders in which anaerobic ciliates have been described.

In the second study – of sandy river sediment – we also determined the number of co-existing (phenotypic) ciliate species and we determined some of the ecological mechanisms facilitating their co-existence. This is probably the first time this has been attempted. The ciliate community consisted of 65 species (8 of which were new), belonging to 50 genera, from 17 orders (Figure. 11). The sediment supported a superficial mat of diatoms (> 30 species). These served as food for at least 16 of the ciliate species. The size frequency distribution of ingested diatoms was almost identical to that for the diatoms in the sediment: thus the probability of a diatom being ingested is probably a simple function of its relative abundance. Two factors were important for the co-existence of ciliate species: wide variation in cell size and shape enabled them to occupy most habitats; and they deployed a variety of feeding mechanisms to consume the variety of microbial food types. Taken as a whole, the ciliate community was capable of feeding on all microbes, including other protozoa, up to a size of about 80 µm. Considering the broad diversity of ciliate habitats available within $1 \ m^2$, the importance of physical transport processes in the river basin, and the known cosmopolitan distribution of many ciliate species, it is believed likely that the species richness we recorded is representative of the expanse of sandy sediment in this river, on this occasion. In addition, the diversity of species found in this small area of sandy sediment may be impressively large but the global total for this type of habitat may not be significantly greater.

Complementary studies are underway to investigate the diversity of other components of these microbial communities. One avenue being explored is the usefulness of transmission electron microscopy, the objective being to determine just how much unambiguous phenotypic information about prokaryote communities can be revealed using this technique. Preliminary information reveals a wealth of morphological and structural detail (Figure. 12) and the certainty that at least 40 different morphological types of bacteria can co-exist in a drop of anoxic lake water.

Microbial processes in freshwater

The specialised equipment and expertise required to obtain good estimates of bacterial activity in natural samples continues to generate interest from contracting organisations. This work has attracted direct financial support for an investigation into the role of bacteria in the bioremediation of hydrocarbon pollution of marine and freshwater environments. Moreover, there has been much demand for the inclusion of microbiological expertise within large multi-disciplinary research contracts. IFE (Windermere) is part of a research consortium, which includes Liverpool and Warwick Universities and the Institute of Terrestrial Ecology, working within the TIGER community research programme. This collaborative work has allowed us to combine activity estimates of bacterial processes with the detection of specific bacterial populations using modern molecular techniques. These initiatives have been particularly successful in the investigation of both nitrifying and methanogenic bacterial communities.

Culture Collection of Algae and Protozoa

Conservation of bio-diversity has been a major focus of both scientific and media attention over the past year. CCAP is one of the largest depositories in the world for cyanobacteria, microalgae and free-living protozoa, so it performs a key role in the preservation of these ecologically important microorganisms.

Long-term preservation techniques are a vital part of the conser-vation strategy. Research carried out in collaboration with The National Institute for Environmental Science (Tsukuba) has improved our understanding of the mechanisms of lethal, freeze induced cell damage in marine members of the Prasinophyceae. This in

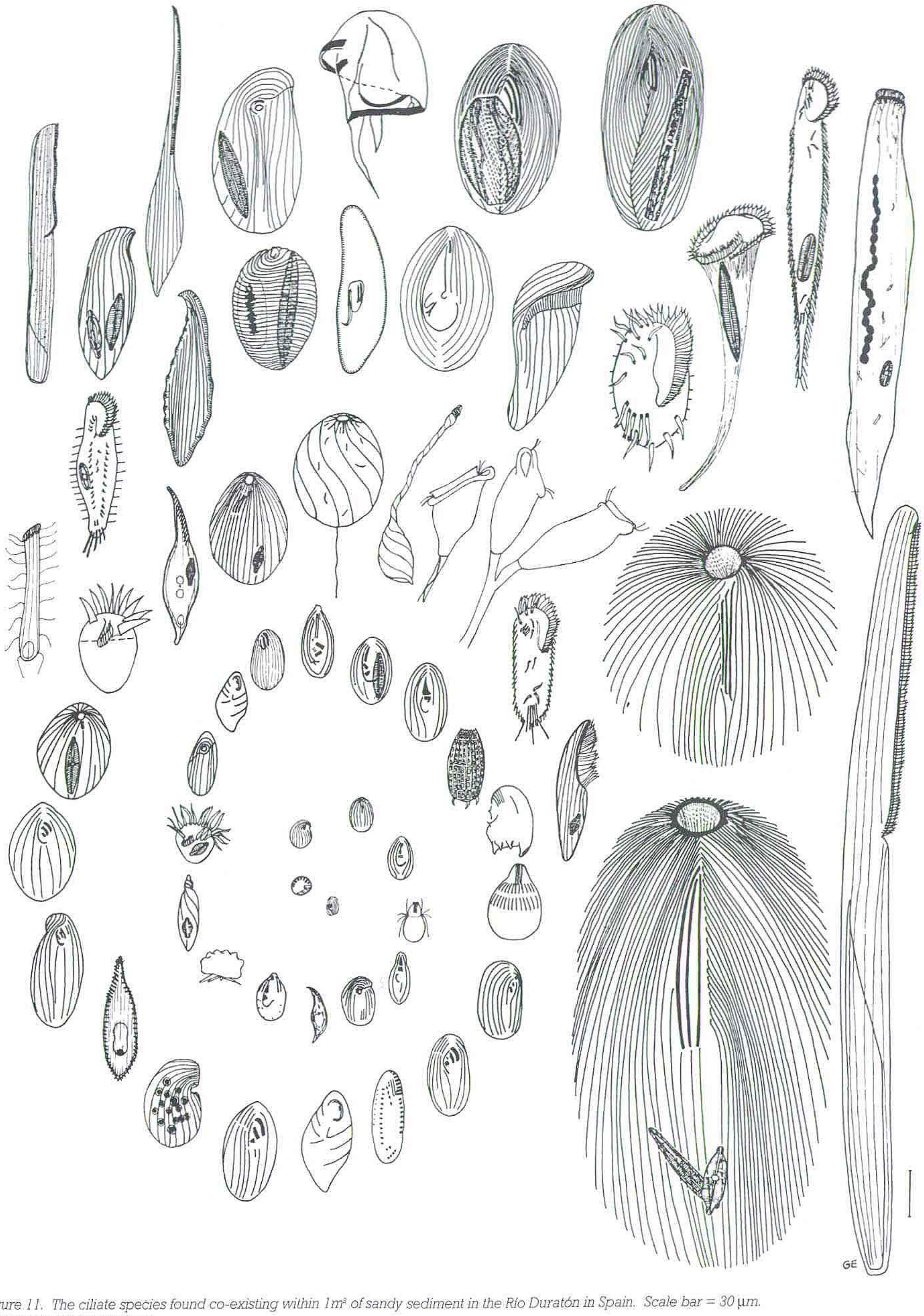


Figure 11. The ciliate species found co-existing within 1m² of sandy sediment in the Río Duratón in Spain. Scale bar = 30 µm. (Artwork by Dr G. Esteban)

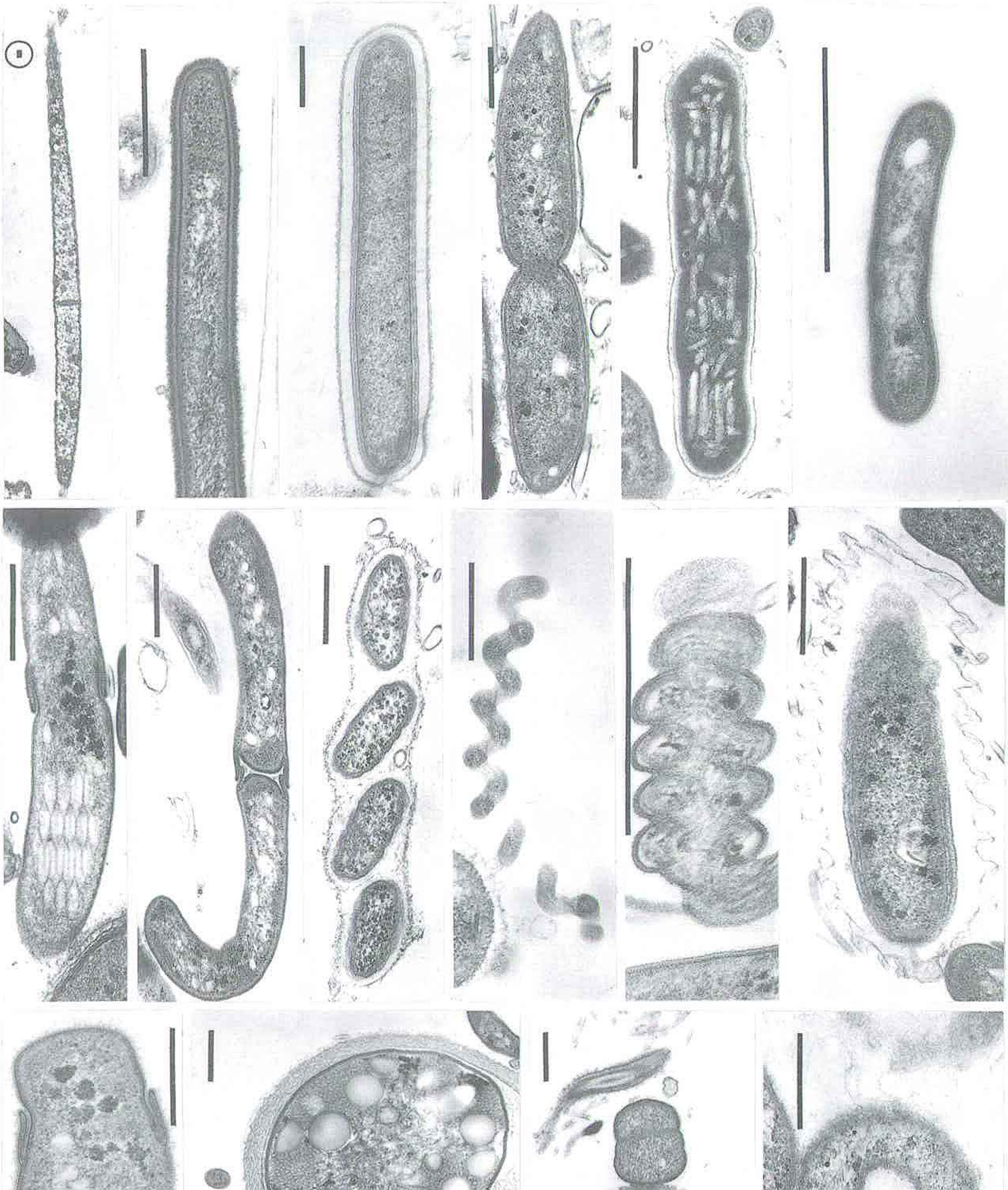


Figure 12. Electron micrographs of some of the bacteria found co-existing in 10 ml of water at a depth of 13 m in an anoxic solution lake in Spain. A total of approximately 40 different bacteria can be discriminated. Scale bar = 0.5 μm.

turn has assisted with the development of non-damaging protocols.

The increased public awareness of the ecological and scientific importance of protists, as well as their biotechnological potential, has resulted in a steady increase in demand for CCAP's cultures, publications and educational resource materials.

Molecular systematics of naked amoebae

CCAP maintains a wide diversity of amoebae which have been described and assigned to species principally using morphological criteria. Molecular biology techniques have recently been applied to test the separation of species within genera. The polymerase chain reaction was used to amplify the small subunit ribosomal DNA (SSU rDNA) of strains held by CCAP (and other collections) representing seven species of the genus *Vahlkampfia* and one species of the closely-related genus *Naegleria*. The amplified SSU rDNA was digested with 16 restriction enzymes and the fragments separated by gel electrophoresis to create riboprints. Computer analysis of the riboprints confirmed the clear separation of seven distinct types within the genus *Vahlkampfia* and revealed the phylogenetic relationships between them (Figure. 13). The results also supported the separtion of the two genera.

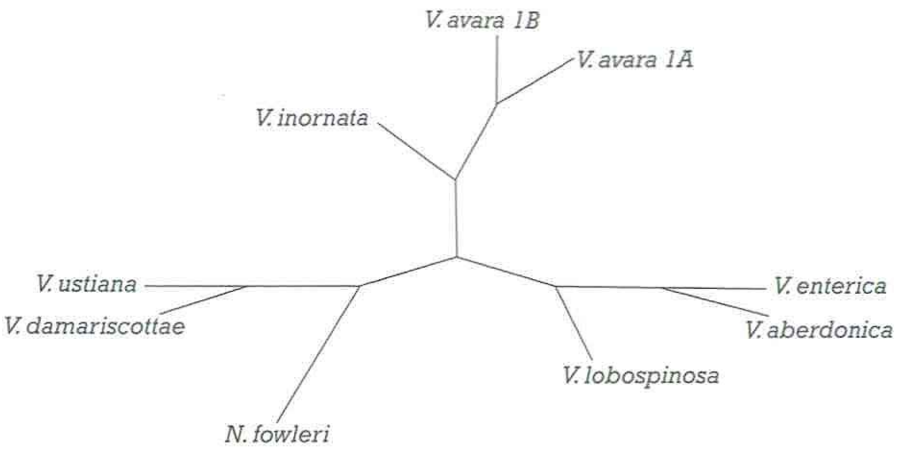


Figure 13. Phylogenetic tree of Vahlkampfia *species, with* Naegleria fowleri *as an outgroup (generated using the Wagner parsimony method).*

Genetics of Freshwater Bacteria

Microcosms

There is a need for suitable laboratory systems to model the fate of genetically engineered microorganisms in the natural environment. Past studies have incorporated the use of many designs and a variety of bacterial strains. This makes it difficult to compare how different strains survive in similar environments. In order to assess the effect of microcosm design, release studies were carried out using one strain in a variety of microcosms.

Results obtained for the survival of *Pseudomonas putida* marked with the *xylE* gene highlighted some limitations of microcosm studies: 1) survival of the recombinant *Pseudomonas putida* PaW8 strain was affected by microcosm design, 2) recovery of culturable cells was influenced by the presence of sediment, aeration, and to some extent by the size of the microcosm, 3) experimental variations (e.g. inoculum concentration) prevent meaningful comparison between microcosms of similar design, 4) microcosms cannot mimic the complexity of natural systems, and it is difficult to attribute effects to a single biological, physical or chemical factor, 5) it may be necessary to use several microcosm designs, simultaneously inoculated with the same strain and the same cell density, to obtain meaningful results.

Aeromonas

Aeromonas salmonicida ssp. *salmonocida* causes furunculosis in salmonids. Previous studies have shown that *A. salmonicida* does not survive for long in water. We have shown that in sterile lake water, it remains viable but non-culturable. For studies of survival in untreated lake water, it was marked with the *xylE* gene and detected by selective plating, and DNA amplification of both the gene and a specific chromosomal DNA fragment. Our results suggest that cells enter a transient non-culturable condition and are detectable in their culturable form for only 21 days. The polymerase chain reaction (PCR) was used to detect non-culturable cells in non-sterile conditions and it was possible to determine when numbers of culturable cells fell below the detection limit for PCR in non-sterile systems. As a consequence, we were able to amplify both the *xylE* gene and a chromosomal marker from populations older than 21 days, confirming the presence of the non-culturable population. We were unable to confirm their viability due to our inability to distinguish the target cells from the indigenous bacterial population.

Physical sorting of different bacteria

The use of fluorescence activated flow cytometric cell sorting to obtain highly enriched monospecific populations of viable bacteria has been achieved in a collaborative project with the University of Liverpool (CASE studentship). Cells of *Staphylococcus aureus*, when mixed in different proportions with *Escherischia coli* could be selectively recovered with an efficiency in excess of 90%. Populations of *E. coli* released into environmental samples were also recovered with similar efficiency. Flow cytometric sorting was used to recover viable target bacteria present at less than 1% of the microbial community. The technique could be extended to the rapid detection of other aquatic bacteria, such as pathogens.

Fish population dynamics and management

Sea-trout catches in England and Wales

Annual rod catches from 67 rivers and annual commercial catches from 36 rivers in England and Wales were analysed in a study financed by the National Rivers Authority. The analyses demonstrated strong positive relationships between large-scale spatial variance (variation in catches between rivers for each year) and spatial mean density (mean catch per year), and also between temporal variance (variation in catches between years for each river) and temporal mean density (mean catch for each river). Both relationships were described by a power function, i.e. the variance-mean relationship was linear on log-log scales (see example in Figure 14).

For spatial variability, there were no significant differences between power functions for both rod and commercial catches from the North West, Welsh and South West regions of the NRA. As the power itself was not significantly different from two, relative spatial variability (measured by the Coefficient of Variation, CV) was fairly constant between years. The relative variation in catches between rivers was therefore fairly constant from year to year and was unaffected by fluctuations in the mean annual catch. This similarity over a large geographical area is remarkable.

For temporal variability, there were no significant differences between power functions for both rod and commercial catches from all five regions (North West, Welsh, South West, Wessex, Northumbria + Yorkshire Esk). A common power function was therefore fitted to the data for all 67 rivers (Figure 14). Once again, the similarity of the relationship over a wide geographical area, as well as between commercial and rod catches, is remarkable.

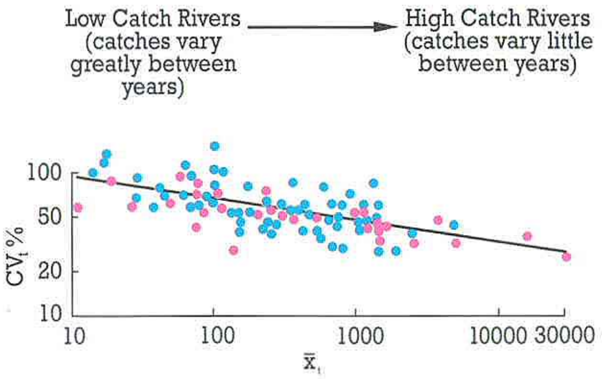


Figure 15. Relationship between the relative temporal variability (measured by the Coefficient of Variation, CV_t expressed as a percentage) and temporal mean density ($\bar{x}_t$ = mean annual catch for each river) for both rod and commercial catches of sea-trout; each point summarizes the data set for a river.

As the power function was significantly less than two, relative temporal variability (measured by CV) decreased significantly with increasing mean catch per river (Figure 15). Rivers with a low temporal CV are therefore nearly all those with high annual catches. Catches in these rivers vary only moderately between years and adult population density must be essentially stable. In marked contrast, rivers with a high temporal CV are chiefly those with low annual catches. Catches in these rivers must vary considerably between years of boom or bust. Previous work on brown trout indicates that these low density populations are governed largely by density-independent factors (chiefly climate), whereas the more stable high density populations are regulated chiefly by density-dependent factors. There are also, of course, medium-density populations affected by both sets of factors. Such differences are important not only for the development of the theory of fish population dynamics but also for the conservation and management of trout

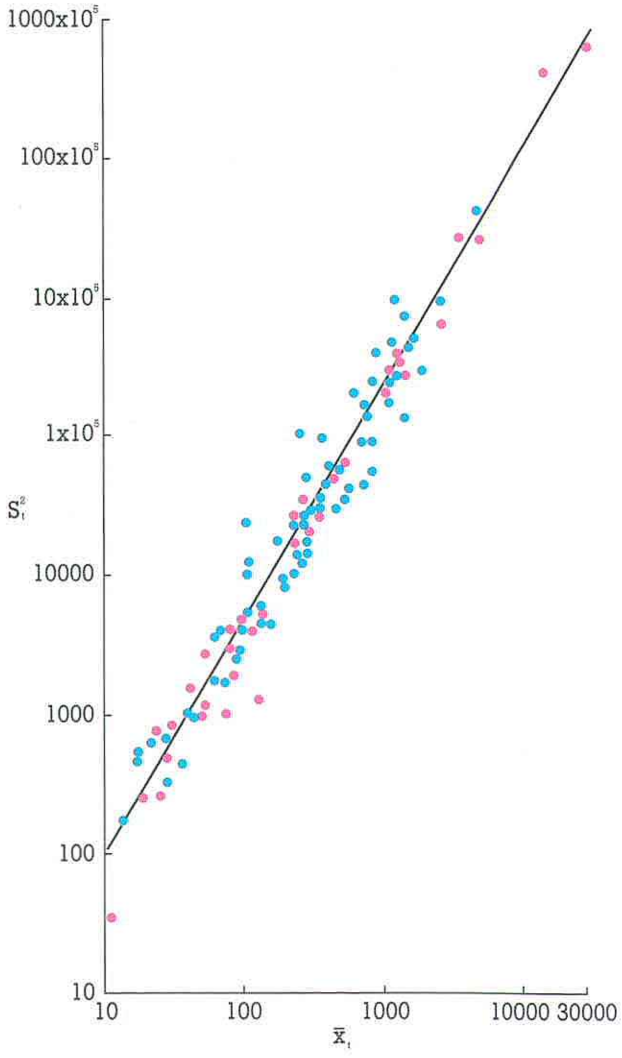


Figure 14. Relationship between temporal variance (s_t^2 = variation in catches between years for each river) and temporal mean density ($\bar{x}_t$ = mean annual catch for each river) for both rod and commercial catches of sea-trout; each point summarizes the data set for a river; note the absence of any significant differences in variance-mean relationship for rod and commercial data, and for rivers from different regions in England and Wales.

populations. However, it is also possible that the differences in temporal variability could be simply due to differences in fishing effort. Further analyses are clearly required.

The relative benefits of stocking with fed and unfed Atlantic salmon parr

Figure 16. Juvenile Atlantic salmon.

These studies form part of a wider contract for MAFF. During 1989, comparisons were made between salmon planted at the time of swim-up and salmon planted after being fed in a hatchery for six weeks (Figure 16). Four experimental channels at Grassholme (Teesdale) were used as simulations of natural streams (Figure 17). Each channel had an area of 10.6 m^2. Two channels were each stocked with 200 swim-up fry to give an initial population density of 18.9 m^{-2}. Two other batches, each of 200 swim-up fry, were reared in two hatchery troughs, each with an area of 1.24 m^2, for six weeks. During this period the fish in the hatchery were given commercial trout food five times a day through an automatic feeder.

Dead fish were removed from the hatchery troughs and counted daily. The fish dispersing from the downstream ends of the channels were caught in nets and were removed and counted daily. After six weeks, the fish from the hatchery troughs were counted and transferred to the other two channels. After a further four weeks, the population in each of the four channels was determined by electrofishing.

The main conclusions were:

(a) During the first week or so in the channels, the salmon planted as swim-up fry rapidly adjusted their numbers by downstream displacement of supernumeraries. During this period none of them showed any measurable growth. After this initial period, growth was rapid and few fish dispersed downstream from the channels. Losses from the channels were about 70% by dispersal and 12% by death, leaving 18% (3.4 m^{-2}) in the channels after 10 weeks.

(b) Losses among fish reared initially in the hatchery and then released in the channels were 17% mortality in the hatchery, 7% mortality in the channels, and 44% loss from the channels by dispersal. About 32% (6.0 m^{-2}) remained in the channels at the end. Growth occurred throughout the period of study but at a lower rate than that shown in later weeks by the fish stocked as unfed fry.

(c) Compared with fish released as unfed fry, salmon reared in the hatchery for six weeks before planting had a higher population density (by a factor of nearly 2) and a lower mean weight (by a factor of 1.4). It is possible that retention in the hatchery partially suppresses the territoriality of the young salmon and thus gives rise to higher population density but smaller mean size.

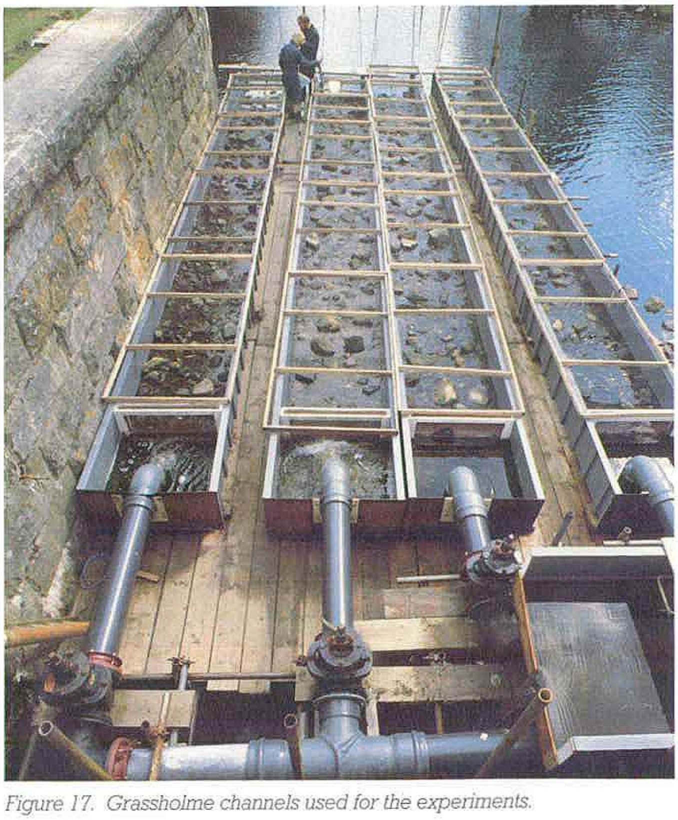


Figure 17. Grassholme channels used for the experiments.

Perch and pike populations of Windermere

Since the mid 1940s, extensive passive sampling techniques in the form of spawning traps for perch (Figure 18) and winter gill nets for pike have been used to monitor changes in abundance and collect specimens for a variety of biological examinations. With funding from MAFF, recent work in collaboration with the Renewable Resources Assessment Group of Imperial College has resulted in the clearing of a backlog of sample processing and the establishment of a relational database incorporating accumulated information on 120,000 perch and 15,000 pike. Of particular note is the fact that the data series now covers long periods before and after the near extinction of perch by disease in 1976. The database now constitutes an invaluable tool for the investigation of fish population dynamics in Windermere and the development of population models of wider applicability.

Figure 18. A Windermere perch trap.

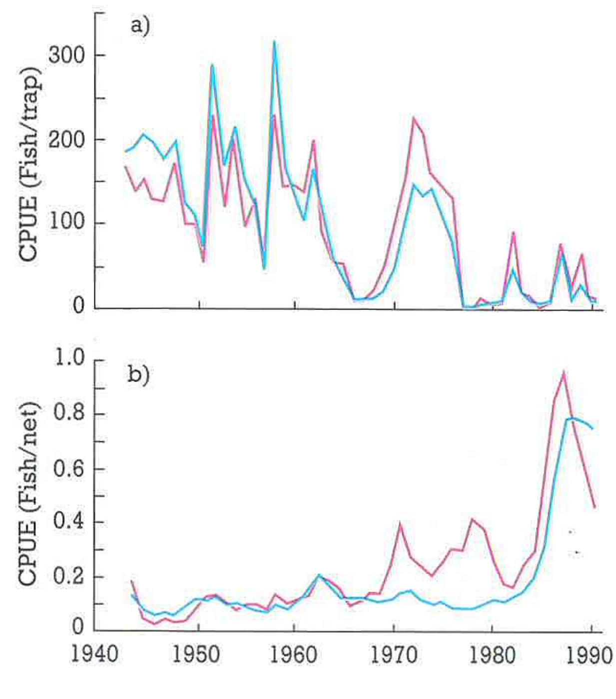


Figure 19. Long-term trends in the observed and predicted abundance (measured as catch-per-unit-effort, CPUE) of (a) male perch, and (b) pike.

The perch data have been used to develop a flexible new population model which allows an estimation of different vulnerabilities and natural mortality rates for males and females by year and age-group, which is particularly appropriate for a fish population affected by large variations in recruitment and adult mortality. A good fit has been achieved with the Windermere perch data (Figure 19a), including the post-1976 time series which has included marked shifts in population abundance. The perch population has not recovered since 1976 and continues to show signs of endemic disease, including being dominated by just two age-classes.

In contrast, catches in the pike fishery, and by implication pike abundance, have been at record levels in recent years (Figure 19b). Mortality has increased for adults, while newly-recruited fish are affected by a combination of increased vulnerability due to faster early growth and decreased natural mortality, the latter feature probably arising from reduced cannibalism on the young fish. The pike population is currently dominated by relatively abundant but short-lived year-classes exhibiting increasing oscillations in numbers.

Work planned for the future includes an assessment of the long-term population dynamics of perch and pike on the basis of capture sites, rather than at simply the whole-lake or basin level. As such, this work will investigate the possible existence of sub-populations of perch and pike in Windermere.

The adaptability of trout to an acidified environment

Despite strenuous efforts to reduce the industrial emissions leading to acid precipitation, acidification of freshwater environments is a continuing problem on a global scale. The results of first field, and then laboratory studies, confirmed that fish kills can be directly related to acid exposure, although the effects of pH are dependent on water hardness (calcium has a protective effect) and the presence of metals, in particular aluminium which is often mobilised into acid waters. Freshwater fish must maintain their internal ionic concentration higher than that of the water around them. They achieve this, in part, by actively pumping ions into the body against the concentration gradient, utilising ion pumps situated on the branchial (gill) epithelium. Exposure of fish to acid conditions is believed to damage this ion-pumping system, causing massive losses of ions across the gills. It is this efflux of ions, rather than acidosis, which is believed to cause death, due to circulatory failure.

Fish have been reported to exhibit some ability to regulate their internal environment in the face of acid challenge. For example, brown trout exposed to moderately acid water (pH 5.0) are able to restore their blood sodium levels to pre-exposure levels. However, exposure of trout to water at pH below 5.0 results in a commonly observed "low pH syndrome" typified by activation of the interrenal tissue, leading to elevated blood levels of the steroid hormone cortisol, increases in haematocrit, plasma glucose and plasma protein. These changes occur concurrently with massive ion losses, reflected in decreased plasma sodium and chloride concentrations. Because cortisol is known to promote ion transport under certain conditions the elevation of cortisol levels observed in such fish has been suggested to be an adaptive response. However, despite this widely-held belief, fish displaying elevated cortisol levels rarely demonstrate full adaptation in terms of their blood ion levels. Thus, until now, the question "do trout acclimate to low pH" had to be answered in the negative.

During a study carried out in conjunction with the University of Nijmegen (The Netherlands), we observed that, under carefully controlled experimental conditions, employing a gradual lowering of the pH, rainbow trout *are* able to acclimate to exposure to pH 4.0 for at least 14 days. During the period of exposure, in which the ambient pH was reduced over a period of 4 hours in the acid-exposed tanks while remaining at ambient in the control tanks (Figure 20), we observed no mortality among the fish from either group, and feeding behaviour was not affected by the reduction in pH. There were no significant changes in a number of indices often reported to alter during acid exposure, including haematocrit and plasma protein levels, although a transient depression of leucocrit was noted and a minor, but significant, hypochloremia and perturbations in plasma glucose level were observed (Figure 21b and c).

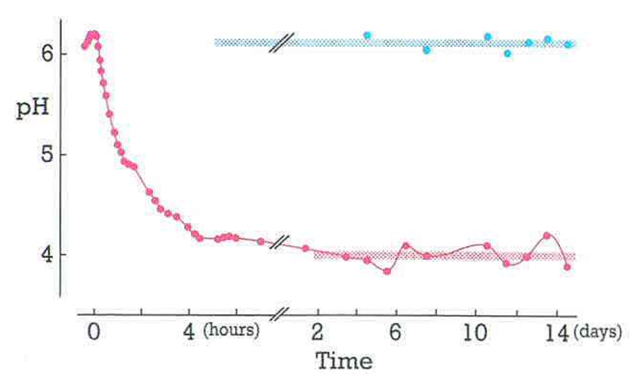


Figure 20. The change with time of pH in the control tanks and in those tanks acidified to pH 4.0 during the 14 day experiment. Each point is the mean with SE of pH in 4 tanks. The shaded areas represent the average pH values ± 1 standard error for the control and acidified tanks from day 2 onwards.

Perhaps most surprisingly, there was no sustained increase in plasma cortisol levels during the period of exposure, in contrast to many previous reports (Figure 21a). It has frequently been suggested that fish under conditions of low ambient pH are more sensitive to additional stressors. Fish from both control and low pH groups did not differ in their responsiveness (in terms of the degree of elevation of plasma cortisol levels) to a 1 hour period of confinement (Figure 21a). Ultrastructural examination of gill tissue by both light and electron microscopy revealed evidence of an increased turnover rate of specialised ion-pumping cells, and an increased infiltration of leucocytes into the gill tissue.

These results indicate strongly that activation of the interrenal and catastrophic ion losses are not inevitable consequences of exposure of trout to pH 4.0, and that the ability of these fish to acclimate to acid conditions may be related to functional alterations in gill structure. The accepted model to explain fish kills at low pH may require some re-evaluation.

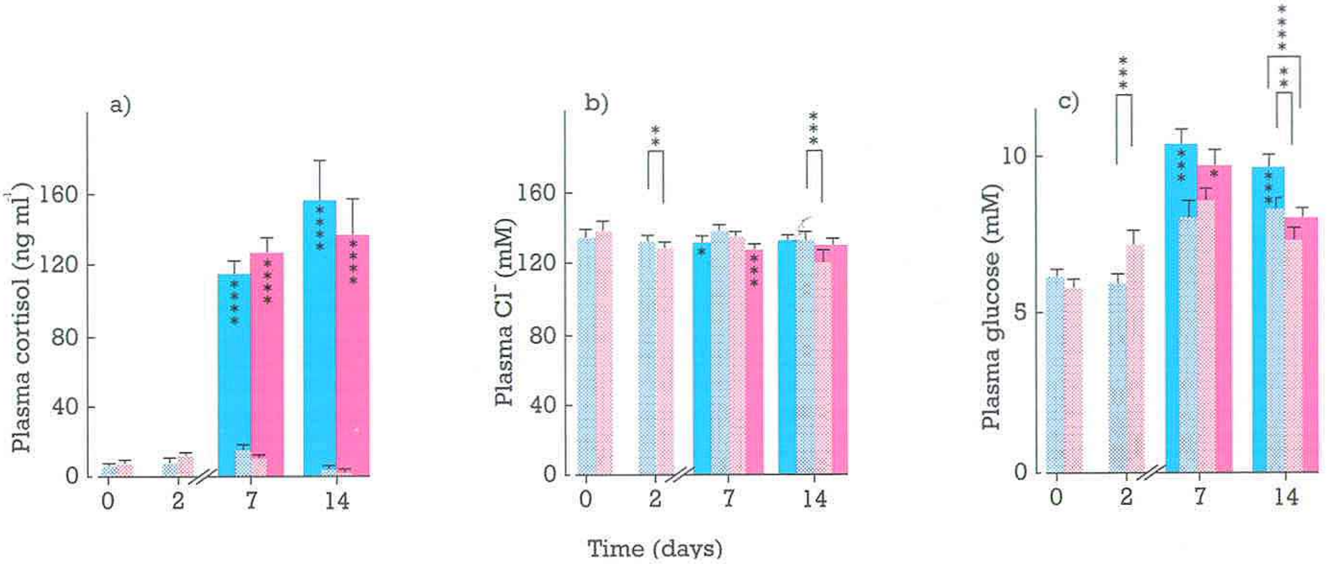


*Figure 21. The levels of (a) plasma cortisol, (b) plasma chloride and (c) plasma glucose, at four points during the experiment, in control fish (stippled cyan) and fish exposed to pH 4.0 (stippled magenta). The values obtained for fish from these groups after 1 hour of confinement stress on days 7 and 14 are also depicted (solid cyan and solid magenta). Each point is the mean with SE, n=16. The effects of stress relative to unstressed values are indicated by symbols within the bars, differences between unstressed pH 4.0-exposed and control fish are indicated by symbols above the bars. * 0.02<p<0.05, ** 0.01<p<0.02, *** 0.001<p<0.01, **** p<0.001.*

Physico-chemical processes in catchments

This project aims to define and predict the physical and chemical features of aquatic ecosystems, on the basis of knowledge about the controlling processes. The work involves both field and laboratory studies, and there is an emphasis on the development of mechanistic mathematical models. Although the main thrust of the work is towards describing natural systems as they presently behave, or will behave in the future, one of our sub-projects takes a step further by attempting the chemical and biological manipulation of an appreciably-sized water body.

Organic pollutants

Upland catchments remote from industrial and agricultural activity are suitable sites to study long-range transport and deposition of organic pollutants. In a project supported by the Department of the Environment, quarterly samples of bulk precipitation and surface water from sites in northern England and Scotland were analysed for 18 pesticides and polychlorinated biphenyls (PCBs). The compounds were analysed by gas chromatography / mass spectrometry.

The herbicide simazine occurred most frequently in rain or snow; it was the only compound regularly detectable in precipitation at all the sites, with a maximum concentration of 30 nanograms per litre. The insecticide lindane occurred in three precipitation samples at 10 nanograms per litre, a concentration some 20 times lower than values recorded at similar sites in the nineteen-sixties. None of the precipitation samples contained detectable concentrations of PCBs. Simazine was detected at a concentration of 20 nanograms per litre in an upland stream in the Lake District, a value more than 10 times lower than is typical for lowland rivers. Simazine was also detected in surface water from north-east England and southern Scotland, together with the insecticides endosulphan, endrin and DDT.

Chemical modelling

The model of ion-binding by natural organic matter (humic substances), reported on last year, has been applied to further literature data, so that parameters for more than 30 metals are now available, including aluminium, heavy metals, lanthanides and actinides. In addition linear free-energy relationships have been established that allow parameters to be estimated in cases where no experiments have been performed with natural organic matter, but where data are available for simpler organic compounds. A new comprehensive equilibrium chemical model has been developed, by combining the humic model with computer codes for inorganic chemistry and several other processes; this is the Windermere Humic Aqueous Model (WHAM), which is applicable to waters, sediments and soils. The modelling effort is being applied in studies of acidification, climate change and the environmental behaviour of radionuclides, and has been funded by Her Majesty's Inspectorate of Pollution, the Ministry of Agriculture, Fisheries and Food, and the NERC TIGER programme.

Radiocaesium in an upland catchment

Previous work had shown that radiocaesium concentrations in the water of several lakes in the Cumbrian lake district remained higher than expected for several years after the Chernobyl accident. To identify the causes of this effect, data that had been collected by the Ministry of Agriculture, Fisheries and Food from Devoke Water (Figure 22), a small oligotrophic lake in Cumbria, were analysed in detail. It was immediately obvious that radiocaesium levels in two of the inflow streams were much higher than those in the lake or in the other streams. Moreover, concentrations in these two streams increased when flows were high, while the other streams showed no flow-dependent variation. With time, however, the concentrations observed in all the streams have decreased.

A soil survey of the Devoke Water catchment, carried out by the Institute of Terrestrial Ecology, showed that both of the streams with higher radiocaesium levels flowed from growing peat bogs, whereas the streams with lower levels emanated from organo-mineral soils. It was possible to show that the flux of radiocaesium in any stream flowing into the lake, at any time after the Chernobyl accident, could be predicted from four variables: the initial deposition of radioactivity, the proportion of peat bog in the stream sub-catchment, the flow rate in the stream, and the time after the accident.

More detailed study of stream radioactivity and chemistry, funded by the Department of the Environment and the

Figure 22. Devoke Water, Cumbria, the site of a detailed study of radiocaesium retention and transport.

European Community, and carried out in collaboration with Energie Nucleare e delle Energie Alternative (Italy), revealed that the different behaviours of the Devoke streams can be explained by different mechanisms of binding of caesium by the soil solids. In the peat bogs, weak ion-exchange by organic matter is principally responsible for the binding, whereas in the organo-mineral soils strong interaction with clay minerals renders the caesium much less mobile.

Fine particles in a riverine "dead zone"

"Dead zones" are bodies of water within a river which exchange with the main flow slowly, relative to advection and dispersion in the main flow itself. In last year's Annual Report, an account was given of the hydraulic characteristics associated with dead zones in the River Severn. That basic work has now been built upon in an investigation of the deposition and resuspension of fine particulate material in a dead zone bed, processes which have implications for benthic communities and the dispersal and accumulation of particle-associated contaminants.

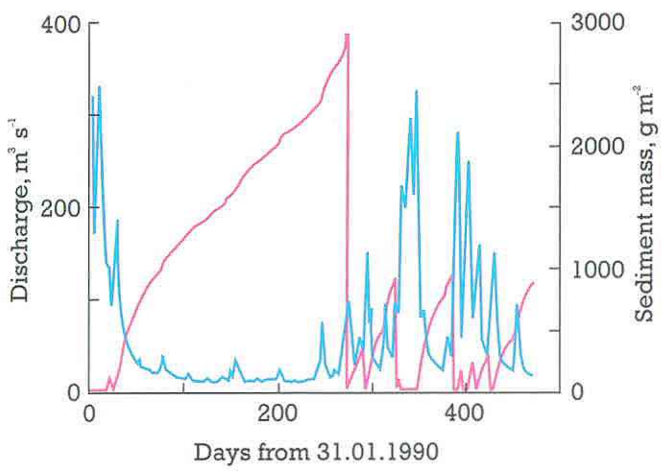


Figure 23. Accumulation and resuspension of fine particulate material in the bed of a "dead zone" of the River Severn, calculated with the Dead Zone Particle Dynamics Model; the plots show how fine sediment mass depends upon discharge

Particulate matter suspended in the River Severn consists chiefly of aggregates of clay-sized mineral particles and living and dead microorganisms (algae and bacteria). Its concentration depends strongly on discharge, but the particle size distribution shows no systematic variability. The volume-averaged mean diameter is *ca.* 9µm, with 95% of the material having diameters between 1 and 50 µm. Accumulation of fine particles in the interstices of the pebble bed of the dead zone occurs when the bed shear velocity is less than about 0.03 ms^{-1}, which corresponds to main river discharges of less than *ca.* 150 m^3s^{-1}. At higher discharges, when the previously "dead" zone becomes turbulent, there is nearly-complete resuspension of accumulated material. A simple mechanistic model of particle dynamics in the dead zone, run with parameter values based on measured particle and hydraulic properties, accounts reasonably well for accumulation rates estimated with particle traps. A long-term simulation with the model (Figure 23) shows that accumulation proceeds continuously during spring and summer, whereas repeated accumulation and resuspension occur during autumn and winter. Calculations with the model suggest that most of the sedimentation flux to the bed is due to material with equivalent sphere diameters of 30 - 240 µm; this consists chiefly of large, low-density aggregates, of which there are only a few per litre of river water.

Figure 24. Seasonal variation in lakewater pH for Seathwaite Tarn in the years 1991 and 1992. The application of phosphate fertiliser was begun in April 1992.

Restoration of an acid lake

Seathwaite Tarn, a 27 hectare lake in the English Lake District, is the site of a field experiment designed to test the feasibility of decreasing water acidity by fertilising with phosphorus. The experiment is to continue for four years, two of which are 'pre-treatment' years followed by two 'treatment' years of regular fertilisation. The first phase of the experiment, completed in 1991, demonstrated that the lake was mildly acid (pH 4.8-5.3) and supported a typical oligotrophic flora and fauna (mean algal biomass 2-3 µg chlorophyll per litre). The regular addition of liquid phosphorus fertiliser in 1992 produced a four-fold increase in the mean algal biomass and an increase of 0.5 units in the summer pH, corresponding to a threefold decrease in acidity. Figure 24 compares lake pH in 1991 and 1992. The pH of the lake was consistently higher in 1992 and rose sharply in early May soon after the fertiliser was introduced. Model simulations indicate that the pH changes recorded in 1992 were consistent with those expected due to the action of phosphorus. At this early stage in the experiment the major acid-consuming process is the assimilative uptake of nitrate nitrogen by growing algae. In the next phase, the dissimilative neutralisation reactions associated with organic decomposition should become increasingly important.

Chemical Analysis

Staff on this project are responsible for chemical analysis at the Windermere laboratory. During the year, approximately 13,500 analytical measurements were performed, distributed among 23 determinands. A new segmented-flow injection apparatus has been purchased, and will soon take over from the now-obsolete discrete analyser for analyses of nutrients. A programme to improve method documentation and quality control is underway, a new computerised database is being developed. As well as performing analyses for IFE projects, the Analytical Laboratory has carried out work for several outside customers.

River ecosystem processes

The status of salmon in the Dorset Frome

There is growing concern over the status of stocks of Atlantic salmon (*Salmo salar* L.) in the British Isles. Catches on many rivers are declining and the chalk streams of southern England are no exception. The IFE has been operating a salmon counter on the R. Frome since the early 1970s. Its accuracy is assessed by time lapse video recording and analysis of the voltage trace signals that operate the counter. The shape of the signal can be used to differentiate between salmon, shoals of smaller fish, eels and other non-fish events such as children swimming through the flume.

There is approximately a fivefold variation between years in numbers of salmon ascending the river with a maximum run of over 4000 fish in 1988. Since this date, the numbers have fallen each year to the minimum recorded value of 804 in 1991. The run in 1992 was also poor with 900 fish ascending.

There are normally three age classes of salmon entering the river. In March and April, three sea-winter fish predominate. These are the largest fish averaging approximately 10 kg. Two sea-winter salmon run mainly in May and June with one sea-winter fish (grilse) running in June and July. A further upstream migration, consisting of fish of mixed age distribution, occurs in the autumn and is often associated with increased discharge events (Figure 25). These are stale fish which entered the river earlier in the year and are moving up to the spawning grounds.

IFE is logging environmental data continuously to be correlated with salmon counts. This will make it possible to predict the factors affecting salmon migration in the river. As the demand for water grows and the need to abstract water increases, particular emphasis is being placed on understanding the relationship between river flow or discharge related factors and salmon movement.

IFE has received funding from MAFF to analyse these data. On the R. Frome, although no decline in total numbers of salmon has been detected, there has been a significant decrease in the catch of spring (three sea-winter) fish. Data from 1991 and 1992 show that the concern over salmon stocks may be justified and a conservation policy, particularly to protect the spring fish, is a reasonable measure to adopt. Whether the problem lies in the marine or freshwater phase of the fishes' life remains an unanswered question.

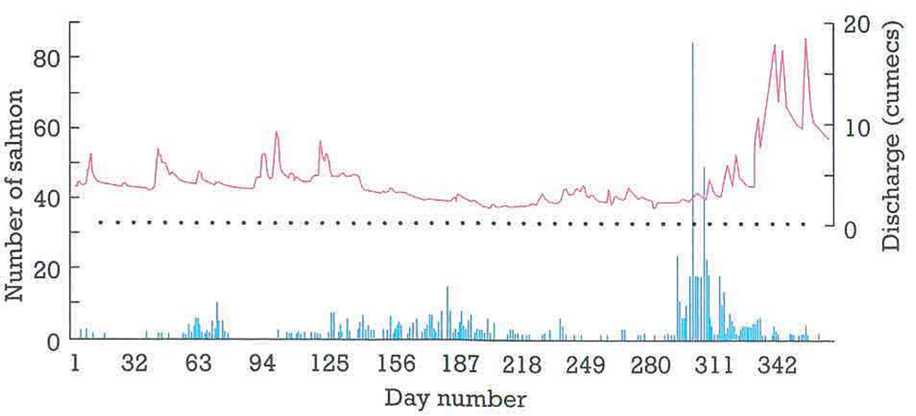


Figure 25. Nett upstream salmon movement, River Frome.

Pesticide movement in rivers

Research on the role of suspended river sediments in the transport of pesticide residues has progressed with studies of the procedures for handling and separation of suspended solids and extraction of the associated pesticides. It has been found that the adsorption of organochlorine pesticides on glass and PTFE containers correlate well with their hydrophobicity as determined by their octanol-water partition coefficients. The triazines do not adsorb significantly to glass or PTFE whereas a-BHC, lindane, dieldrin and endrin are weakly adsorbed. The pyrethroid insecticides are strongly adsorbed to most materials. The retention of pesticides on different membrane filters used to separate suspended sediments from the water, is variable with the lowest uptake generally on the filters of inorganic composition. In spite of these difficulties, procedures have been developed to separate the particulate matter from turbid samples and analyse these by rigorous extraction procedures and gas chromatography.

These methods have been applied to the determination of the pesticide content of suspended solids from different rivers. A joint project with the Postgraduate Research Institute for Sedimentology (PRIS), at the University of Reading has applied these methods to examine the distribution of simazine, atrazine, prometryn, lindane, DDE, dieldrin, DDT, heptachlor and parathion in river water, bed and suspended sediments at three sites on the River Windrush in Oxfordshire. The mineral composition of the sediments was related to the source minerals in the immediate area. The traditional link between the pesticide concentration in the sediment and the concentration of total organic carbon or organic matter was not always evident, particularly at the upstream sites. Other factors such as the surface area per gram of sediment and amount of clay in the sediment appeared to control the association of most of the pesticides. For compounds which exhibited a good correlation between their concentration and the organic carbon content of the sediments, an equally good correlation was found with the surface area of the particulates. In this catchment the mineralogy of the local soils and soil structure combined with the surface run-off from agricultural land, are thought to be important influences of pesticide movement to the rivers.

Conflicts of interest in designing environmentally sound channels

Design, management and maintenance of irrigation and drainage channels may exacerbate the processes of channel deterioration by encouraging sedimentation and excessive aquatic weed growth. Traditionally-designed channels are often straight with simple cross sections (a shape rare in nature) to make the best use of labour or heavy machinery etc. Straight channels have a tendency to meander. This results in erosion and deposition but does not necessarily reduce their hydraulic efficiency; thus, they do not need to be dredged back to their design criteria.

Channels are frequently designed without due consideration to the subsequent development of vegetation and its effects. Aquatic plants will normally be present in natural waters if light, nutrients and suitable sites are available. Their rate of growth, however, depends upon the intensity and duration of light which they receive and the physical conditions of the water, its movement, temperature, clarity and chemistry. Plant growth continues progressively, creating a more complex habitat typical of those species involved.

Environmentally-sound techniques used to moderate plant growth take advantage of the potential for limiting these key growth controlling factors but require detailed knowledge of the biology of the existing species and of other potentially invasive plants. For example, whilst many *Ranunculus* species require rapid and shallow water and can easily invade sites, Nymphaceae can tolerate deeper, slower and even long periods of turbid water because they can carry over stored materials from year to year in large rhizomes; they may, however, take years to become fully established in such sites. The presence of floating plants is highly variable and responsive to factors such as water flow or wind but may also be highly dependent upon refugia from which they recolonise after adverse periods or they may rely upon the presence of enormous seed banks.

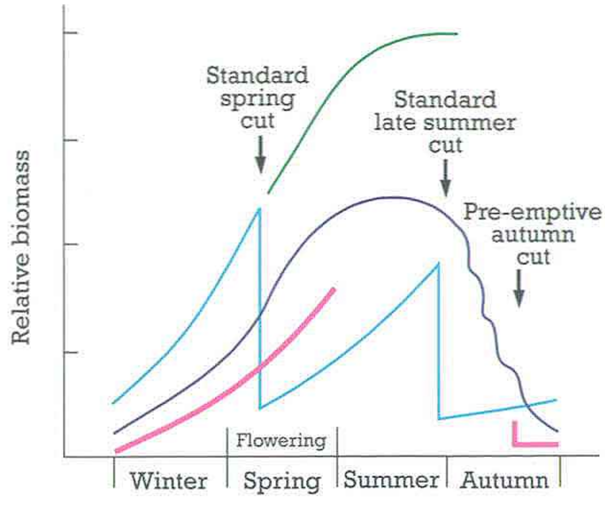


Figure 27. Preemptive weed control of a typical submerged plant of flowing waters.

Traditional mechanical control (Figure 26) is often associated with an ongoing commitment of men and machines. Such schemes may be re-directed by progressively implementing changes, such as spatial modification in removal i.e. cutting only those parts of the channel necessary for flow maintenance. Alternatively temporal alteration of practices such as preemptive control, which anticipates the growth and implements removal prior to it, thereby reducing the necessity for bulk removal and disposal of plant material, may be effective. (Figures 27 & 28)

Apart from changes in channel design alternative control can be achieved through growth-controlling factors which include: light reduction by encouragement of marginal vegetation (Figure 29); opaque covers at the water surface; reduction of the light penetration of the water by natural or artificial means including animal activity, eg by bottom-feeding fish such as carp; and, even artificially enhanced algal populations may in some circumstances be effective.

In these ways habitat modification and changes to management practices can reduce maintenance effort especially in combination with existing practices. However, whilst the benefits of environmentally-sound policies and practices can be cost effective and improve channel behaviour, research is still necessary to resolve conflicts of interest which attend inexpensive water transfer in conventional channels. There is also a need for the future improvements in design and construction of self sustaining channels having minimal maintenance requirements.

Figure 26. Removal of water hyacinth from a drainage canal, Egypt.

Figure 28. Small drainage canal, South Australia, showing herbicide treated canal bank with nearby herbicide resistant plants.

Figure 29. Small river showing effects of partial shade reducing weed growth.

Assessment and prediction of changes in the aquatic environment

Introduction

A feature common to each of the four items selected for this year's report, is the reliance on sound analytical and interpretive skills accrued through maintaining programmes that are commonly and dismissively referred to as 'routine', 'monitoring' and 'observational'. To the contrary, such studies provide records of change and baselines against which environmental impacts can be assessed. They are proving crucial to an understanding of some of the effects of such topical phenomena as climate change, eutrophication and acidification, and the use of biological and chemical indicators of these processes. Two studies relating to planktonic diatoms in Lake Windermere draw on records extending back nearly half a century, while work on nitrate levels in Southern English streams refers to a 30-year database, and investigations on rotifers (a relatively neglected group of freshwater organisms) in Loch Leven, Scotland cover a 14-year period.

Lake Windermere phytoplankton

The performance of *Asterionella formosa* in the South Basin over 45 years.

The data collected as part of the routine monitoring programme extend back to 1945 for a number of Cumbrian lakes and its extent, completeness (weekly or fortnightly samples) and scope (a wide range of physical, chemical, and biological variables are measured) make it unique. These data provide an opportunity to check for long-term change and to try and understand why any change has taken place.

Asterionella formosa Hass. is a pennate diatom (Bacillariophyceae) and a major component of the algal population in spring and autumn in many temperate mesotrophic and eutrophic lakes. The average seasonal pattern of change, based on records between 1946 and 1990 in the South Basin of Windermere, has been described (Figure 30).

Particular descriptors of this annual pattern were then analysed to determine if long-term change had occurred using two simple models of change: either a monotonic change or a two-phased change hinged on the mid-year of 1968. Of the 19 characteristics, 11 showed no long-term trends, but eight showed statistically significant trends (Figure 31). For example, the concentration of cells at the end and the beginning of the year has declined over the period, and linked to this, the day on which cell concentrations exceeded 50 ml^{-1} occurred later each year. The subjectively-determined start of the period of exponential rise in the spring showed a long-term trend, becoming earlier by 19 days from 1946 to 1968 and then later by 38 days from 1968 to 1990. The maximum rate of rise in the spring showed a significant long-term increase with calculated rates of 0.065 $\log_e$ day^{-1} in 1946 and 0.112 $\log_e$ day^{-1} in 1990.

The precise environmental causes of change are not easy to determine, particularly if 'chaos' is playing a role. Nevertheless, attempts are currently underway to model the seasonality of certain species, testing this against the records in the database, in order to gain a better understanding of the effects of physical, chemical and biological factors on the performance of given species or functional types. For example, the increase in the maximum rate of rise in the spring appeared to be the result of the more favourable light-climate in the late spring since there was a strong positive correlation between the rate of rise and the day of start of exponential rise.

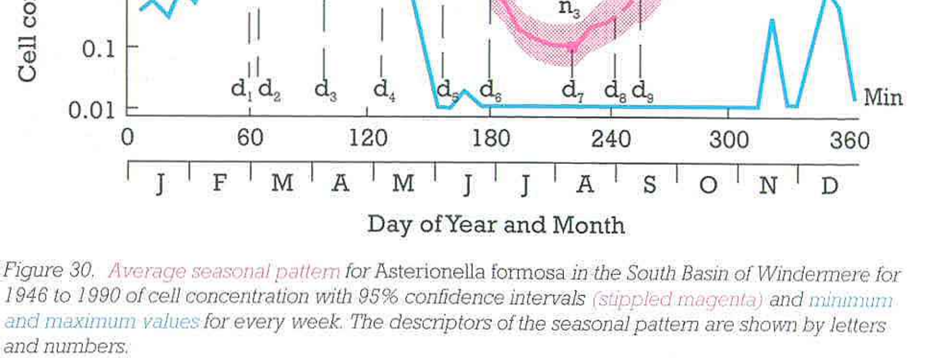


Figure 30. Average seasonal pattern for Asterionella formosa *in the South Basin of Windermere for 1946 to 1990 of cell concentration with 95% confidence intervals (stippled magenta) and minimum and maximum values for every week. The descriptors of the seasonal pattern are shown by letters and numbers.*

Plankton and sedimentary records

Recent reappraisal of the diatom assemblages in the sediments that have accumulated in the South Basin of Windermere over the last 100 years shows the successive increase of eutrophic water taxa. ^{210}Lead analysis now dates the base of the increase in the first indicator - *Asterionella formosa* Hassell - as c. AD 1890 rather than 1800 or 1850 as previously thought and demonstrates that lake enrichment closely followed the effluent input from the then newly opened sewage treatment works. Local Council records show that there were considerable problems with sewage disposal in the latter half of the nineteenth century resulting in a new joint plant for Windermere and Bowness, sited close to the lakeshore and discharging treated effluent into the top end of the South Basin. The rate of lake response, unremarked at the time, illustrates the lack of foresight in such a decision.

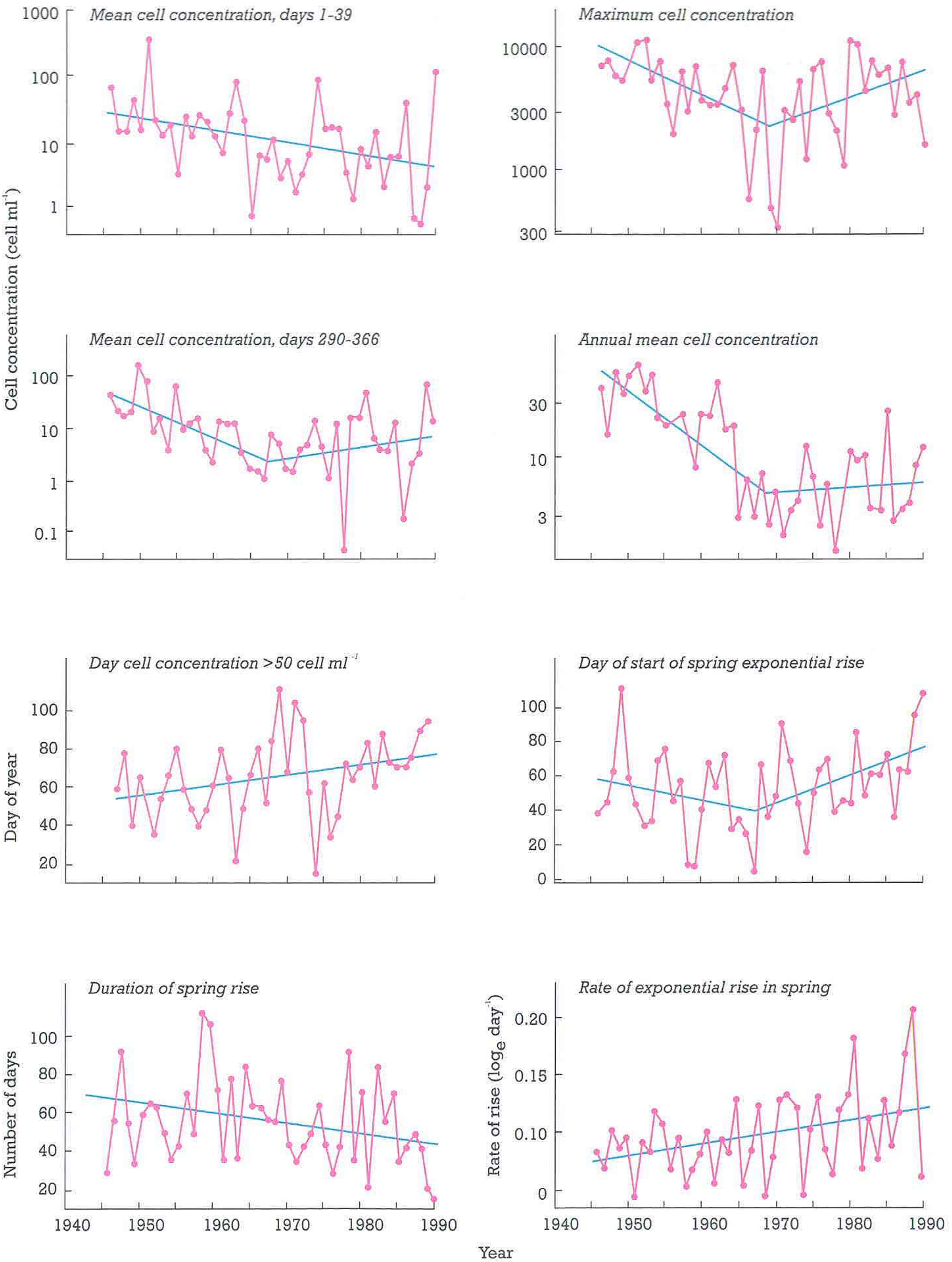


Figure 31. Long-term trends in descriptors of the seasonal pattern of Asterionella formosa *in the South Basin of Windermere. The regression line of best fit is shown.*

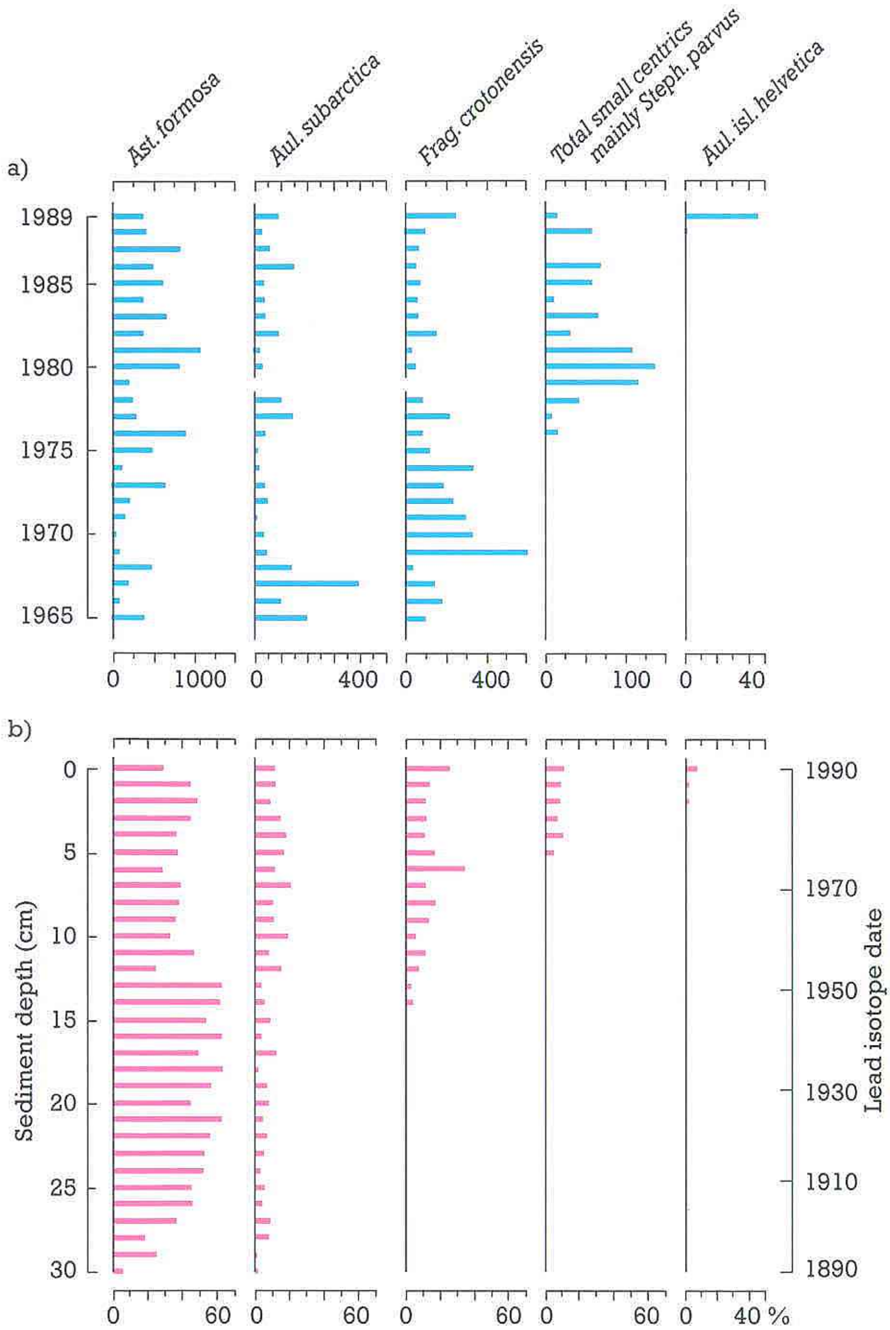


Figure 32. Windermere South Basin: comparison between (a) diatom plankton as the average cells $ml^{-1}\,yr^{-1}$ from IFE Algal Database and (b) the sedimentary record of these taxa as % of the diatom assemblage (analyst S. Sabater).

Within the top 10 cm of sediment that represents the last 30 years, there are obvious increases in *Aulacoseira subarctica* (O. Müller) Haworth, *Fragilaria crotonensis* Kitton and its variety *prolongata* (Grunow) de Toni, *Stephanodiscus parvus* Stoermer & Håkansson and lastly, *A. islandica* ssp. *helvetica* O. (Müller) Simonsen. Together with some clear peaks in accumulation of other diatoms, these provide several alga-dated horizons in the sediments and the sediment diatom assemblage profile can be readily matched with the long-term phytoplankton records generated by the Institute. (Figure 32)

Although the Windermere phytoplankton records exist for only the last 50 years or so, they provide the essential means for interpreting environmental shifts from the fossil record. The continued increase in recognised diatom indicators of enrichment occurred over the period, post-1960, when there was a steep increase in phosphate concentrations in the lake, the mean winter concentrations rising from less than $5 \mu g\, l^{-1}$ to c. $24 \mu g\, l^{-1}$.

As part of the NERC TIGGER Programme the long-term plankton records and detailed sedimentary stratigraphy are now being compared for the North Basin of Windermere. The focus is on the effects of short term changes in climate. The value of this type of correlation has been considerably enhanced by the verification of a good sequence of laminated sediments in the top metre.

Nitrate levels in Southern English chalkstreams

The River Laboratory has been studying the flow and chemistry of Southern English chalkstreams for thirty years and has built up a unique data set on these subjects.

Seasonal, long-term and short-term changes in nitrate concentrations has been related to changes in land use, fertiliser applications and pollution due to sewage effluent. Surveys of the River Frome catchment in 1970-71 and 1984-86 have shown that nitrate concentrations and loads have increased at eight sampling sites on the main river and its tributaries. The River Frome catchment at that time was mainly grassland with only 25% of the land used for cereal production. Recommended nitrogen fertiliser applications to grasslands has increased from 26.3 kg N ha^{-1} in 1960 to 114 kg N ha^{-1} in 1984.

NO_3N concentration (mg N l^{-1})	**Dorchester**	**East Stoke**
1970-71		
mean	2.32	2.78
minimum	1.54	1.94
maximum	4.46	3.92
1984-86		
mean	3.67	4.22
minimum	1.59	2.50
maximum	5.33	6.40
Nitrate loads (tonnes $week^{-1}$)		
1970-71		
mean	3.64	10.09
minimum	0.90	3.11
maximum	13.35	34.09
1984-86		
mean	7.23	17.54
minimum	1.31	4.44
maximum	25.30	24.25

Frequency histogram of the range of nitrate concentration (mg N l^{-1}) over the period 8 July 1987 - 5 April 1988.

Daily Range	No of Days	% of Days	
0.0 - 0.49	76	38.4	********************
0.5 - 0.99	75	37.9	*******************
1.0 - 1.49	31	15.7	********
1.5 - 1.99	10	5.0	*****
2.0 - 2.49	3	1.5	*
2.5 - 2.99	3	1.5	*
Total	**198**	**100.0**	

Values found at sampling sites on the River Frome at Dorchester and East Stoke demonstrate the large increases found both in nitrate concentrations and loads between the periods 1970-71 and 1984-86.

In 1985 the annual nitrate load at Dorchester showed an increase of 121% since 1970-71 while the corresponding increase at East Stoke was 81%.

A nitrate monitor has been developed in conjunction with Hull and Plymouth Universities and used for intensive monitioring taking samples every 30 minutes over a ten-month period on the River Frome at East Stoke. The results from the monitor were compared with routine samples to see how well a routine weekly sample can adequately represent the true nitrate record. The average of the weekly samples was 4.60 mg N^{-1}. This was 0.30 mg N l^{-1} less than the average of the values using the continuous sampler. The ratio of the weekly value to the continuous sampler mean never exceeded 1.08, but on one occasion was only 0.64 - a 36% underestimation.

Rotifers as indicators of environmental change

Rotifers are microscopic animals which are found in almost every type of brackish and freshwater environment. Although, as a group, their distribution is widespread, many individual species are found only where certain conditions prevail and it has been suggested that these have considerable potential as biological indicators.

This certainly seems to be true in Britain. Work carried out at the Edinburgh Laboratory and based on rotifer collections from 48 Scottish waterbodies and 1 English tarn, shows that planktonic rotifers may be very sensitive indicators of water quality, especially where there is concern over acidification or nutrient enrichment. For example, *Keratella serrulata*, believed to be an indicator of acid environments, was found in only 8 of the waterbodies sampled, but these constituted all of the study sites which were known to be affected by acidification. In addition, waters with high total open water phosphorus (P) concentrations contained many species which have been proposed as indicators of eutrophy, while potential oligotrophic indicator species were most often found in waters with relatively low total P levels (Figure 33). In general, eutrophic 'indicators' were seldom found where total P levels were below 12 µg l^{-1}, while oligotrophic indicators were rare in water with more than 50 µg l^{-1} total P.

Results from a long-term surveillance of Loch Leven, Kinross-shire, also suggest that rotifers could be used as monitors of environmental change. Their appearance in or disappearance from a particular location seems to indicate changing conditions. The species list for this site remained virtually unchanged for more than 14 years. Then, in the summer of 1991 the oligotrophic indicator species, *Kellicottia longispina*, suddenly appeared in large numbers. This seems to have been one of the first indications of an effect of the significant reduction of P inputs to the loch in the late 1980s.

Oligotrophic — Rotifers – Trophic indicator species → Eutrophic

Loch	Open water P. conc. (µgl^{-1})	*Conochilus unicornis*	*Ascomorpha ecaudis*	*Gastropus stylifer*	*Kellicottia longispina*	*Ascomorpha ovalis*	*Polyarthra vulgaris*	*Polyarthra dolichoptera*	*Keratella cochlearis*	*Polyarthra euryptera*	*Lecane lunaris*	*Euchlanis dilatata*	*Pompholyx sulcata*	*Brachionus angularis*	*Keratella quadrata*	*Filinia longiseta*
Shiel	7.1			●	●			●	●							
Eck	8.1				●		●		●							
St Mary's	8.2				●		●		●							
Veyatie	9.3				●			●	●							
Clunie	11.4				●			●	●		●					
Craiglush	11.4				●				●		●					
Lindean	13.8	●		●	●				●						●	
Branxholme Easter	15.7	●		●	●		●		●						●	
Lowes	15.7	●			●				●			●			●	●
Asta	16.2			●		●	●		●							
St. John's	16.6				●		●	●	●						●	
Tingwall	17.6		●	●			●	●	●	●						
Spiggie	22.8							●	●							
Butterstone	23.8						●	●	●		●	●				
Marlee	26.2				●				●							
Brow	26.6							●	●							●
Davan	32.8							●	●						●	
Linlithgow	38.6			●				●		●					●	
Cliff	39.9				●											
Coldingham	49.5								●						●	
Balgavies	57.1						●	●	●				●	●	●	●
Strathbeg	61.1														●	●
Rescobie	79.5								●				●	●	●	●
Mill	92.4								●						●	●
Kilconquhar	1252.3															

Figure 33. Rotifer indicators of trophic status in relation to measured open water P concentration of 25 Scottish lochs.

Laboratory Services

The library and information service

The library

Scientific papers and reports relevant to the Institute's objectives have continued to appear at the rate of approximately 10,000 a year and our library catalogue consequently continues to grow at this rate. Although we have been producing our records in digital format for the last ten years, for various reasons it has not been possible to produce a computerised catalogue. During the 1992/93 financial year we obtained a copy of the UNESCO sofware CDS/ISIS. In liaison with our colleagues at the Plymouth Marine Laboratory Library and Information Service, we developed the necessary formats and systems in order to be able to produce a computerised catalogue. A short pilot exercise was completed successfully and we began to add records to the system from the beginning of January 1993. We have usable digital records back to January 1987 and we will begin to convert these and add them to the CDS/ISIS system during the 1993/94 financial year. It is planned to have the records from 1987 searchable over a local area network by 1994. The card catalogue will continue to be maintained until this service is available. Retrospective conversion of the whole catalogue and production in various formats will be explored.

One of the part time administration posts in the library at Windermere, funded as casual labour, was lost during the year. A full time Administrative Officer post has been converted to a job-share and in this way we have managed to maintain the necessary skills base to continue the full range of services.

We thank once more the staff of the Institute of Terrestrial Ecology libraries for their help and cooperation in providing services to IFE scientific staff at Edinburgh and Monkswood.

The information services

The selective dissemination of information from Current Contents on Diskette, the Current Awareness service, the personal bibliographic systems using Pro-Cite software, and the retrospective retrieval services using both online and CD-ROM sources continued to be well used. Software refinements were made throughout the year in order to accommodate new requirements such as the new computerised catalogue system. The Environmental Chemicals Data and Information Network (ECDIN) compact disk database was added to the existing databases in this format. Access to the range of Citation Indexes was enhanced using the BIDS system available over the JANET (Joint Academic Network).

Contracts

In addition to its role of assisting the scientific staff with bibliographic work relating to their contracts, the library continued to undertake contract work in partnership with the scientists. Two such contracts were completed during the year – a literature review of phytoplankton as a technique for atmospheric purification in submarines and a report on the biology of hydroids on the Cumbrian coast.

The contract work between the Joint Research Centre, Ispra, Italy and the library continued in two areas. Further data summaries and editorial work were carried out for the ECDIN database, and a survey and summary report was prepared on the environmental fate of 50 chemical substances which have a major application as active ingredients in pharmaceutical preparations. Janet Dobson, who undertook much of this work, left the Institute in January and this contract post has not been replaced.

An agreement was reached between the Department of the Environment, HMSO, and the Institute enabling the reports of contracts undertaken by the Institute for DoE to be made more generally available. Copies can now be purchased through Department DWS.

Networks

The provision of input to the Aquatic Sciences and Fisheries Abstracts (ASFA) database has fallen even further behind due to pressure of other work. Higher priority will need to be given to this next year.

Contact and collaboration with the various associations of aquatic sciences libraries and information centres was maintained as was contact with the Cumbria Environmental Information Service and the network of educational organisations in the North West.

The Freshwater Biological Association

The services provided to members of the Freshwater Biological Association continue to be well used. Take up of the services offered to the staff of the National Rivers Authority under the FBA/NRA Technical Service Agreement has also continued to grow throughout the year.

The donation by Dr Alan Brennan of his collection of chironomid reprints was gratefully received and will be a useful addition to the library stock. Anna Benning successfully completed her Information Science Fellowship with the FBA Library in October. Her information and marketing skills were a tremendous asset in the continuing development of the FBA library services.

Electronics and instrumentation

A very heavy workload of repair and maintenance work has acted to limit the new developments by the department. However, despite this, significant progress has been achieved in several areas.

Water current profile recorder

A system originally developed about a decade ago was significantly updated. An array of six rotary flow sensors ('ottmeters') were interfaced to a Husky Hunter 16 environmentally sealed, hand-held microcomputer. The system allows simultaneous recording from each sensor and thus a six point vertical profile of water current to be measured.

Sediment detector

A standalone optical sediment detector was constructed and supplied to the Environmental Chemistry Department at the University of Lancaster. The sensor was based on that supplied with the 'Windermere Profiler 2' instrument. When the sensor detects the presence of lake sediment, a simple control box provides the operator with both an audible warning and a clear message on a liquid crystal display visible even in direct sunlight. The detector allows water samples to be abstracted from a defined height above the undisturbed sediment, enabling processes at the sediment/water interface to be studied in detail.

Deployment of data loggers

A 'thermistor chain' was deployed in Devoke Water as part of the CHECIR (Chernobyl International Research Centre) project and a long-term environmental pH monitor was deployed in Esthwaite Water as part of the project 'Responses of freshwater plankton to temperature and CO_2'.

Repairs

The computer terminal and equipment repair service continues to be appreciated by other NERC sites. More than 50 repairs were carried out during the year, half of them in one day at BGS Murchison House following a lightning strike on the building!

Major installations

The department has been closely involved in placing and overseeing the contracts for the renewal of the River Laboratory telephone system as well as the new fire alarm installations at both the River and Windermere Laboratories. Significant progress has also been made in improving the electrical distribution at the River Laboratory, including the provision of new underground ducts connecting the main building to various outbuildings. Further work will be required in the coming year.

Safety

Steps have been taken to ensure compliance with recent legislation and updated regulations in the area of electrical safety at all IFE laboratories.

Property, Buildings and Equipment

Changes to laboratories and offices during this period have been minimal, limited to the continuation of the replacement window programme in the Ferry House.

A number of changes have taken place related to general security on the Windermere site, ie

a) An "intelligent" fire detection system has been installed which is linked to a remote monitoring station.
b) All normal access doors now feature coded locks, either mechanical or electro-mechanical.
c) A site location has been established from which the handling of any major incident would be co-ordinated.
d) Manned security hours have been altered to include daylight hours at weekends.

Following a number of problems at the Lartington site, an alarm system has been installed, along with a steel safe which is used to store petrol generators and outboard engines.

During the summer of 1992, Peter Allen led a team which undertook the repair and rebuilding of the artificial streams at Lartington. This period of intensive heavy work involved:

a) emptying and dismantling the 4 gravel filled channels
b) pressure washing and inspecting the support structure
c) repairing and replacing the support structure as required
d) rebuilding the system, having replaced all of the supporting timberwork.

The completion of this work ensured several more years of safe and satisfactory operation of the channels.

A decision was taken to stop supplying petrol on the Windermere site because of the steadily rising cost of meeting safety requirements. In future the petrol tank will store diesel fuel and any new vehicles purchased will run on this.

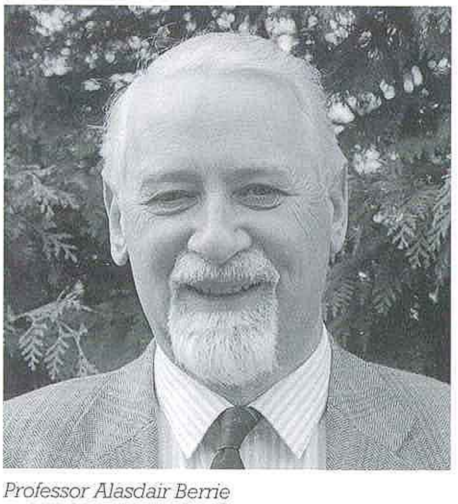
The up-grading of fire doors and the fitting of door view panels continues the process of improving fire and safety standards on the site.

Work started in late 1992 on the preparation of the specification for the re-roofing of Ferry House, in the hope that the work would be undertaken during 1993.

Staff and external activities

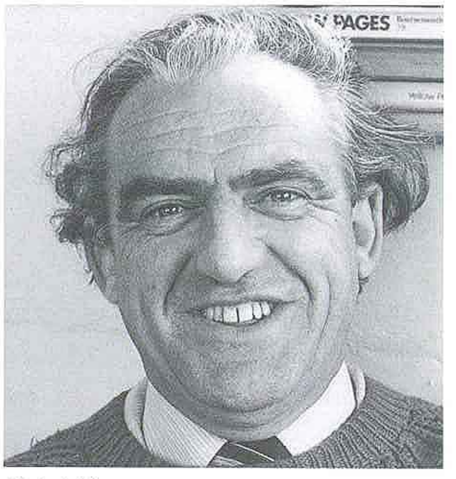
Staff changes

Professor A.D. Berrie retired in January after 20 years in charge of the River Laboratory. Alasdair was also Head of Southern Division with responsibility for Eastern Rivers Laboratory as well as the River Laboratory and acted as Co-ordinator of Commissioned Research for IFE. Since his appointment to FBA in charge of the River Laboratory Alasdair has helped his colleagues weather the storms of adapting to contract work, threats to the future of the River Laboratory, the enforced redundancy situation and to the changes stemming from the establishment of the Institute of Freshwater Ecology from the former grant-aided Freshwater Biological Association. Alasdair has been made an Honorary Research Fellow of FBA and will now have time to write up some of his research studies and will also have the opportunity to keep in touch with colleagues at the River Laboratory and at the IFE.



Professor Alasdair Berrie

Mr J. Morgan retired in July. Jack joined the staff of the River Laboratory in November 1963 while construction work was still in progress. As Laboratory Steward he was in charge of a group of staff responsible for technical services, building and grounds maintenance, ordering and issuing stores, vehicles, cleaning and security. In addition his technical skills were utilised in the design and construction of various experimental facilities and equipment.



Mr Jack Morgan

Miss N. Lund and Mrs S. Smethurst resigned from posts at the Windermere Laboratory and Mr A.G. Shand from the River Laboratory. Mrs J. Dobson, Mr M.T.R. Hill and Miss P. Southern left Windermere Laboratory at the end of their contracts and Miss A.T. Moran left to take a Veterinary degree at Cambridge University. Dr R.K.M. Saunders took up an appointment at the University of Hong Kong.

Several new colleagues were welcomed as replacements or additional staff. Mr D. Cordwell replaced Mr J. Morgan at the River Laboratory, Miss R. Bainbridge and Mrs V. Muzalewski replaced Miss N. Lund and Mrs Smethurst at Windermere. Mr N. Grieve was appointed to join the land-river interactions team at the River Laboratory and Mr L. Nolan to the chemistry team at Windermere.

The number of staff in post at 31 March 1993 was 102.

Honours and promotions

Professor Jones was elected as the next President of the Society for General Microbiology and will take over his duties as President in September 1993.

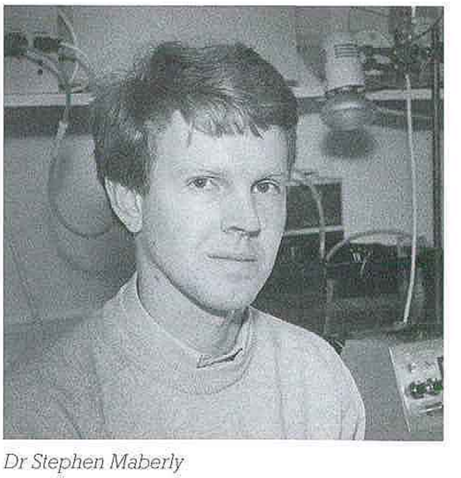
Dr S.C. Maberly received the Luigi Provasoli Award for the outstanding papers in *Journal of Phycology* from the Phycological Society of America.

Dr B.J. Finlay was awarded Individual Merit Promotion to Grade 6 for the excellence of his research on protozoa. Dr M. Ladle was promoted to Temporary Grade 6 while acting as Officer in Charge at River Laboratory following the retirement of Dr Berrie. Mr R.J.M. Gunn was promoted from Higher Scientific Officer to Senior Scientific Officer, Miss J.E. Corry (now Mrs Parker) from Scientific Officer to Higher Scientific Officer and Miss H.G. Orr from Assistant Scientific Officer to Scientific Officer.

NERC activities

Mr Beaumont and Mr Glaister were members of Executive Committee of the NERC Branch of the Institution of Professionals, Managers and Specialists and Mr Beaumont also served on the NERC Whitley Committee and NERC Health and Safety Committee. Professor Jones served on Promotions Panel Grade 7. Professor Pickering was a member of the committee for the Special Topic on Wildlife Diseases. Dr Elliott was a member of the Aquatic Life Sciences Grants Committee and of the NERC Visiting Group which inspected MSc courses. Dr Dawson acted as secretary of the Expert Review Group on Wetlands.

IFE staff have been involved as members of committees or working parties of the major research programmes Land Ocean Interaction Study (LOIS) and Terrestrial Initiative in Global Environmental Research (TIGER). Dr Hilton, Professor Jones and Dr Tipping were members of LOIS committees and Dr Cranwell and Dr House were members of LOIS chemical and biological working party.



Dr Stephen Maberly

The Terrestrial and Freshwater Sciences Directorate (TFSD) of NERC, of which IFE is part, divides its research activities into major programmes. Professor Berrie, Dr Elliott and Dr Tipping were core group co-ordinators and Dr Bailey-Watts, Dr Cranwell, Mr Pettman and Dr Reynolds were core group members. Mr Casey and Dr Cranwell were members of TFSD Analysts Working Group and Dr Cranwell a member of the Organic chemistry mass spectrometry advisory committee. Dr Pinder was a member of a TFS Working Party on Environmental Change Network for Rivers. Mr Rouen was a member of TFSD Computing Group.

Collaboration with other NERC Institutes

There has been continued collaboration with both Institute of Hydrology (IH) and Institute of Terrestrial Ecology (ITE) on the major research programmes TIGER and LOIS and many staff are involved in varying aspects of these programmes with Professor Jones and Dr Tipping involved in TIGER and Mr Casey, Dr House, Professor Jones and Dr Tipping with LOIS.

Professor Pickering has collaborated with IH and ITE regarding joint commissioned research projects. Dr Armitage and Dr Ladle have collaborated with colleagues in IH on ecologically acceptable flows and the development of physical habitat simulation (PHABSIM) models. Dr Crisp and Mr Beaumont have a joint project with IH on upland trout populations. Dr Pinder, Dr Wright and Mr Bass have collaborated with colleagues in ITE on a study of the effect of drift of aerially sprayed pesticides; on testing and development of RIVPACS; and on invertebrate fauna of farmland ditches.

Staff from Edinburgh, Windermere, Teesdale and the River Laboratories have been involved with ITE Banchory on an ecological assessment of Loch Lomond Water management proposals. Dr Bailey-Watts has collaborated with ITE to study the effects of fish removal on nutrient and plankton dynamics and on invertebrate benthos structure in an Aberdeenshire loch. Mr Glaister has been involved with ITE Banchory into an assessment of engineering work on River Leven. Dr Pickup has collaborated with staff at ITE Merlewood on a desk study into the release of genetically engineered microorganisms and Dr Hilton over the joint use of a gamma counter.

Dr Tipping has collaborated with British Geological Survey (BGS) colleagues on Measuring and Modelling Radionuclides Interactions with Natural Organics and Professor Jones has collaborated on commissioned research. Dr Hall has collaborated with ITE Merlewood, Furzebrook, Banchory and BGS Wallingford on a contract for Department of Transport and with the Marine Pollution Control unit on the disposal of oiled leach materials in coastal environments. Dr Carling has a joint project with the Proudman Oceanographic Laboratory. Mr Clarke has taken part with the British Antarctic Survey into a study of blue-green algal composition of fell-field soils.Close links are maintained with Dunstaffnage Marine Laboratory through the joint maintenance of the Culture Collection of Algae and Protozoa.

Scientific Societies

Professor Jones was elected President Elect of the Society of General Microbiology and a member of its International Committee for Microbial Ecology and Dr Pickup was Convener of Environmental Microbiology of the Society. Dr Dawson was a Council member of the Institute of Biology and a member of its Environment Committee, and Mr Mann a member of the Water Industry sub-committee of the Institute. Mrs Hurley was a committee member of the Royal Statistical Society Cumbria & Lancashire Local Group. Mr Mann & Dr Winfield were Council members of Fisheries Society of British Isles, and committee members of the East Anglian and North West Branches respectively of Institute of Fisheries Management and Dr Winfield is a member of the organising committee for the 1994 annual study course of the Institute. Mr Pettman was chairman of the Britain & Ireland Association of Aquatic Sciences Libraries & Information Centres and UK representative on the European Association of Aquatic Sciences Libraries & Information Centres. Dr Day was Newsletter Editor for the UK Federation of Culture Collections. Dr Tipping was a member of the Board of Directors of International Humic Substances Society. Mrs Hindle acted as organiser of the British Section of the Society of Protozoology Conference held in Ambleside in April 1993.

Other organisations

Dr House was a member of the European Community (EC) Bureau of Reference Materials Panel on an interlaboratory study of Polar pesticides and Dr Tipping was co-ordinator of topic area Particles and Aggregates at a Commission of the European Communities (CEC) meeting on Cohesive Sediments.

Dr Bailey-Watts was a member of the Impact of Nitrogen Deposition on Terrestrial Ecosystems Committee of the Department of the Environment (DoE); Dr Elliott was on the Biological Methods Panel of the DoE Standing Committee of Analysts and a member of the DoE Health and Safety Advisory Committee on Releases to the Environment; and Dr House was a member of DoE Technical Committee on Detergents and the Environment. Professor Jones was a member of the Department of Trade and Industry Link Committee on Biological Treatment of Soil and Water. Mr Beaumont was a member of the steering group for UK Acid Waters Monitoring Network. Dr Armitage was a member of the Biological Methods Committee, and Dr Carling a member of the Sediment Transport sub-committee of the British Standards Institute.

Dr Crisp was a member of the National Rivers Authority (NRA) Regional Fisheries Advisory Group for Northumberland; Dr Ladle a member of both the NRA Regional and Local Fisheries Advisory Groups for Wessex: Dr Dawson a member of the NRA Conservation Classification Advisory Group; Dr Reynolds a member of the NRA Toxic Algal Task Group. Dr Bailey-Watts served on the Forth River Pollution Board, on a Scottish Office Working Party on Cyanobacteria and as a member of Loch Leven Area Management Advisory Group. Dr Elliott served on a Working Group on Salmon & Sea-trout set up jointly by Ministry of Agriculture Fisheries and Food and the Scottish Office Agriculture and Fisheries Department. Dr Ladle continued as chairman of the Fleet Study Group and as a member of the River Allen Association Advisory Panel and Dr Wright as a member of the Moors River Standing Committee. Dr Carling was a member of the American Society of Civil Engineers Task Force on Mechanisms of Non-Newtonian Fluids.

Dr Reynolds continued to serve as a member of the Office of Water Services Consultative Committee for the North West, as an elected member of South Lakeland District Council where he served as Chairman of its Environmental Health Committee and of Kendal Town Council where he had the honour of serving as the 357th Mayor of Kendal. Mr Pettman was a panel member of Cumbria Environmental Information network.

Dr Irish was Chairman of the Ambleside and District Chamber of Trade. Miss Atkinson continued to serve as a Secretary of State's Appointed Member of the Lake District Special Planning Board and as a member of its Development Control Committee, Park Management Committee and Vice-chairman of its Planning Policy Committee and also as a member of the Conservation, Access and Recreation Advisory Committee of North West Water Company.

Editorial commitments

Dr Finlay was Editor of *Archiv für Protisenkunde*. Professor Jones edited *Advances in Microbial Ecology* and Mr Pettman was editor of *New Library World* and *Librarians World*. Dr Cranwell was Associate Editor of *Organic Chemistry*. Mr Mann, Dr Pottinger and Dr Winfield were Assistant Editors of the *Journal of Fish Biology*. Dr Reynolds was Sub Editor for *Archiv für Hydrobiologie*.

Staff served on the Editorial or Advisory Board of the following journals, Dr Armitage *Regulated Rivers*, Dr Crisp *Hydrobiologia*, Dr Elliott *Annales de Limnologie* and *Wasser und Abwasser*, Dr Finlay *Journal of Protozoology*, *FEMS Microbial Ecology*, *European Journal of Protistology* and *Microbial Ecology*, Dr Haworth *Journal of Palaeolimnology*, Dr Maberly *Aquatic Biology*, Professor Pickering *Diseases of Aquatic Organisms*, Dr Mann *Ecology* of *Freshwater Fish*, Dr Pickup *Microbiology*, Dr Reynolds *Aquatic Sciences*, *Journal of Plankton Research* and *Limnologica*, Dr Tipping *Environmental Technology*.

Collaboration with universities

Teaching

Professor Jones is a Visiting Professor at the University of Liverpool and Professor Pickering a Professor Associate at Brunel University. Dr Tipping is a Visiting Reader at the University of Lancaster. Dr Carling, Dr Pickup and Dr Winfield were Visiting Lecturers at the University of Lancaster and Dr Pickup and Honorary Research Fellow at the University of Liverpool. Dr House, Dr Ladle and Dr Wright were Honorary Lecturers at the University of Reading and Dr Bailey-Watts at the University of Edinburgh. Dr Dawson was a Visiting Fellow at the University of Southampton.

Dr Bailey-Watts contributed to a course on Water Resource Management for MSc students at Napier University. Dr Crisp gave lecture courses on Fisheries to MSc students at Durham University and to Lancaster University students. A course on River Ecology was run for the Institute of Hydraulic and Environmental Engineering, Delft, by Dr House and a RIVPACS case study by Dr Wright for Reading MSc students.

Staff acted as external examiners for PhD degrees at the following Universities:– Birmingham (Dr Bailey-Watts), Cardiff (Dr Ladle), Lancaster (Mrs Hurley), Liverpool (Dr Wright), London (Dr Winfield), Manchester (Professor Jones and Dr Reynolds), Newcastle upon Tyne (Dr Carling), Stirling (Dr Bailey-Watts) Uppsala Universitet (Dr Reynolds) and Dr Elliott was an examiner for a DSc degree at the University of Wales.

Research

Dr Armitage continued studies on minimum ecological flows with Loughborough University; on slow sand filters with University College, London and on aquatic benthos and the chironomids of Tenerife with Universities of Umea and La Laguna. Dr Bailey-Watts has continued collaboration on studies on phosphorus in lake sediments and metals in sediments with the University of Edinburgh, on plankton ecology of Loch Ness with Lancaster and on diatom ecology with University of Lund. Mr Casey has collaborated with Plymouth University on design and application of FIA for Field Monitoring. Mr Clarke has continued studies on anaerobic environments in sulphide rich lakes with University of Valencia and commenced a study on parasites of bacteria with University of Girona. Dr Finlay continues his joint research projects with University of Copenhagen and with University of Konstanz. Dr Haworth has collaborated with Deakin University, Australia on taxonomy, with University of Liverpool on palaeolimnology, with Lancaster on the Seathwaite project and with Royal Holloway College and University College, London on the Terrestrial Initiative in Geological Global Environmental Research (TIGGER). Dr Hilton pursued joint studies with the University of Manchester on radioecology of Thorium, with the University of Leuven on defining a sorption surface; with University of Cork on testing microelectric analytical equipment. Dr House collaborated with the University of Reading on a pilot study on source-sediment controls on riverine transport of herbicides and with Birmingham University on the development of biofilms. Dr Ladle has carried out joint research with the University of Oxford on Fish Pheromones and life history strategy. Professor Jones and Dr Pickup have an active programme of collaboration with the Universities of Liverpool and Newcastle. Dr Pottinger continues to collaborate with Brunel University on studies of the role of the newly discovered pituitary hormone somatolactin in fish and with the University of Nijmegen on the mechanisms by which combinations of low pH and aluminium exert toxic effects on fish. Dr Reynolds is collaborating with Universities of Leeds and Manchester on algae and phosphorus storage. Dr Tipping has a joint project on soil-radionuclide interactions with the University of Lancaster.

Members of staff acted as supervisors for higher degree students registered at the following universities:

Miss E. Baroudy (Lancaster – PhD) Effect of eutrophication on Windermere charr populations, with Dr Elliott.

Mr A. Brown (Luton – MSc) The macroinvertebrate fauna of contrasting microhabitats in a lowland chalk stream, with Dr Armitage.

Miss S. Brown (Liverpool – PhD) The molecular systematics of anaerobic protozoa and their prokaryote symbionts, with Dr Finlay.

Miss C. Bryant (Edinburgh – PhD) Trace element chemistry in water and sediments of diverse lake systems, with Dr Bailey-Watts.

Miss P.S. Davies (Leeds – PhD) Competition for phosphorus in the control of phytoplankton community structure, with Dr Reynolds.

Mr D. Deere (Liverpool – CASE student – PhD), with Dr Pickup.

Miss A. Fulcher (Lancaster – PhD) The physiological ecology of the rotifer community in the plankton of Loch Ness and the Cumbrian lakes, with Dr May.

Mr R. Garcia-Ruiz (Malaga – PhD) The release of soluble phosphorus from particulate wastes in the effluent from fish farms, with Dr Hall.

Mr P. Garner (Loughborough – PhD) Fluvial effects on the distribution of 0-group cyprinids in the River Great Ouse, with Mr Mann.

Miss B. Guhl (Konstanz – PhD) Studies on the symbiosis between anaerobic protozoa and methanogens in freshwater sediments, with Dr Finlay.

Mr R. Hastings (Liverpool – PhD), with Dr Pickup.

Mr R. Head (Lancaster – PhD), with Dr Bailey-Watts.

Mr N. Hesketh (Manchester – PhD) The binding of hydrophobic organic molecules by humic substances, with Dr Tipping.

Mr A.T. Ibbotson (London – PhD) Habitat relationships of freshwater fishes, with Dr Ladle.

Mr A. Kelsey (Lancaster – PhD) Modelling sediment transport, with Dr Carling.

Miss K. Lawlor (Liverpool – PhD) Detection of recombinant bacteria, with Dr Pickup.

Miss H. Llorens-Forcada (Valencia – MSc) An epibiont of the photosynthetic bacterium *Chromatium weissei* and its complex life-cycle, with Mr Clarke.

Miss S. McGowan (Liverpool – PhD) Palaeolimnology of the Shropshire Meres, with Dr Haworth.

Mr I. Miskin (Liverpool CASE student – PhD), with Dr Pickup.

Miss S. Owen (University College, Cardiff – PhD) Sorption and biodegradation of pesticide/surfactant formulations in biofilms on river sediments, with Dr House.

Mr R. Poles (Glasgow Caledonian – MSc) Environmental factors which determine the performance of freshwater phytoplankton: analysis using a long term database, with Mrs Hurley.

Mr J. Porter (Liverpool – PhD) Detection of specific bacteria, with Dr Pickup.

Mr G. Rhodes (Liverpool – CASE student – PhD), with Dr Pickup.

Mr J. Smith (Liverpool – PhD) Modelling the transport of Pb-210, Cs and Am – 241 in the aquatic environment, with Dr Hilton.

Miss J.A. Taylor (Dundee – PhD) Immunofluorescence of picoplankton, with Dr Heaney.

During the year five research students were awarded PhD degrees: Miss P.M. Campbell (Brunel), Mr W. Hiorns (Liverpool), Mr I.D. Hooper (Southampton), Miss J.R. Marchesi (University College, Cardiff), Mr A.J. Spink (Glasgow) and Miss A. Meachin (Lancaster) was awarded an MSc with distinction.

International meetings and visits

Dr Bailey-Watts visited the Central Inland Captive Fisheries Institute, Barrackpore, India and presented a paper relating to tropical fisheries management and drafted a research project. He presented a seminar paper on Eutrophication at the University of Pertanian, Malaysia; and at the University of Chiang Mai, Thailand joined by Dr Pinder took part in a teaching workshop on Biological Monitoring of Water Quality. Dr Carling undertook joint research projects in Colorado and Montana (USA) and Coblenz (Germany) and visited South Africa to discuss research collaboration and Mr Glaister joined him in field work in Montana and on the Rhine. The International Microbial Ecology Congress held in Barcelona was attended by Mr Clarke who presented two poster papers, and by Dr Finlay, Professor Jones and Dr Pickup who acted as session chairmen. Mr Clarke carried out field work with University of Valencia at three lakes in Central Spain. Dr Dawson was a speaker at the International Workshop on Ecology and Management of Invasive and Riparian plants. Dr Day presented a paper at the 7th International Congress for Culture Collections held in Beijing, China and visited the National Institute for Environmental Science in Tsukuba, Japan. Dr Elliott was keynote speaker at International Symposium on the Ecological Basis for River Management held at Leicester at which Mr Mann and Dr Reynolds presented papers and Dr Armitage attended. Dr Finlay made two research visits to Spain, to Madrid and to Cuenca. Dr Haworth was guest speaker at a Symposium on Biological Indicators of Global Change held in Brussels and presented a joint paper at the International Diatom Symposium in Holland. Dr Hilton was keynote speaker at a UNESCO meeting in Paris and visited The Netherlands, Portugal and Russia in connection with a CEC research project on Chernobyl.

Dr House presented papers at a SETAC meeting in Potsdam, Germany and a meeting on Phosphorus Cycling in Terrestrial and Aquatic Systems held in Hungary and visited the EC Bureau of Pesticide Reference Materials in Brussels. Professor Jones made two visits to Argentina to prepare an EC research proposal and to help with a university teaching programme. Dr Maberly presented a paper, a poster and acted as session chairman at the Aquatic Plant Management Society Meeting and the International Symposium on the Biology and Management of Aquatic plants held in Florida and he also undertook collaborative research at Gainsville Florida. Mr Mann attended the Symposium on Fish Life History Strategies and is co-editor of the Proceedings. Dr May was a member of the scientific committee for the 7th International Rotifer Symposium. Mr Pettman attended the annual meeting of the International Association of Aquatic and Marine Sciences Libraries and Information Centres held at Bremerhaven and visited the Station d'Hydrobiologie Lacustre, France for library cooperation. Professor Pickering was organiser of the Symposium on Pathological Conditions of Wild Salmonids held in Aberdeen and a keynote speaker and Dr Elliott was also a keynote speaker. Professor Pickering was Workshop organiser of 2nd International Symposium on Fish Endocrinology held in St Malo, invited speaker at the *Saprolegnia* in Salmon Symposium held in Portland, Oregon and Workshop participant at a meeting held in Holland on Adaptation. Dr Pinder visited the Danube Research Station, Budapest and Lake Balaton Research Station to discuss research projects. Dr Reynolds presented a keynote paper at a joint meeting of the American Society of Limnology and Oceanography and British Ecological Society held in Cork and visited Budapest for an editorial meeting. Dr Tipping presented invited papers at the European Scientific Foundation Research Conference on Organic Matters in Natural Waters in Espino, Portugal and at a US Environmental Pollution Authority Workshop on Aquatic Life Criteria for Metals held in Annapolis. Dr Winfield visited Norway in connection with analysis of data collected from Loch Ness as part of Project Urquhart. Dr Wright chaired a session at the Societas Internationalis Limnologiae (SIL) Congress at Barcelona and presented a paper at the Biological Monitoring Workshop. Dr Bailey-Watts received Mrs S. Boronsombat (Chiang Mai University), Mr D. Mandere (Fisheries Institute, Malawi), Prof F. Md. Yusoff (Universiti Pertanian Malaysia) at the Edinburgh Laboratory for training in limnological methods.

The Freshwater Biological Association

The Freshwater Biological Association is an independent body that conducts research into all aspects of freshwater science. The programme is maintained by awarding grants and studentships, usually to young scientists. The Association works in close collaboration with the Natural Environment Research Council's Institute of Freshwater Ecology.

By agreement with the NERC, the FBA conducts its research programme in the Laboratories now managed by the Institute of Freshwater Ecology. The Windermere Laboratory (The Ferry House) is the Head Office of the Association and the other laboratories are:

The River Laboratory, East Stoke, Dorset
The Eastern Rivers Laboratory, Huntingdon, Cambridgeshire
The Teesdale Laboratory, Barnard Castle, Co Durham
The Edinburgh Laboratory, Penicuik, Midlothian

Membership is open to individuals and organisations that wish to support the Association. Members receive copies of the Association's Freshwater Forum, and may obtain other publications at a discount; they may also visit the Laboratories, and use the Library by agreement with the Director.

The Library provides a suite of services including the following:

Current Awareness Service. A monthly publication listing recent articles, reports and books covering all aspects of freshwater science is available from the Library and Information service for an annual subscription.
The British List of Hydrobiological Papers is published annually, listing papers on British fresh waters, arranged geographically.
A Document Delivery Service supplies photocopies of articles and papers from the extensive range held in the library.
Literature Searches will be undertaken by the library staff.

All of these services are available at reduced rates to members of the Association. Further details are available from THE LIBRARIAN, THE FERRY HOUSE, FAR SAWREY, AMBLESIDE, CUMBRIA LA22 0LP.

In addition to its programme of research and publication, and the maintenance of International Archives such as the FBA Library and Fritsch Collection, the Association organises a range of meetings. These include conventional scientific symposia and major international seminars. It is also envisaged that smaller workshops and training courses will play a larger part in the future programme.

All enquiries concerning Membership and the Association's activities should be addressed to:

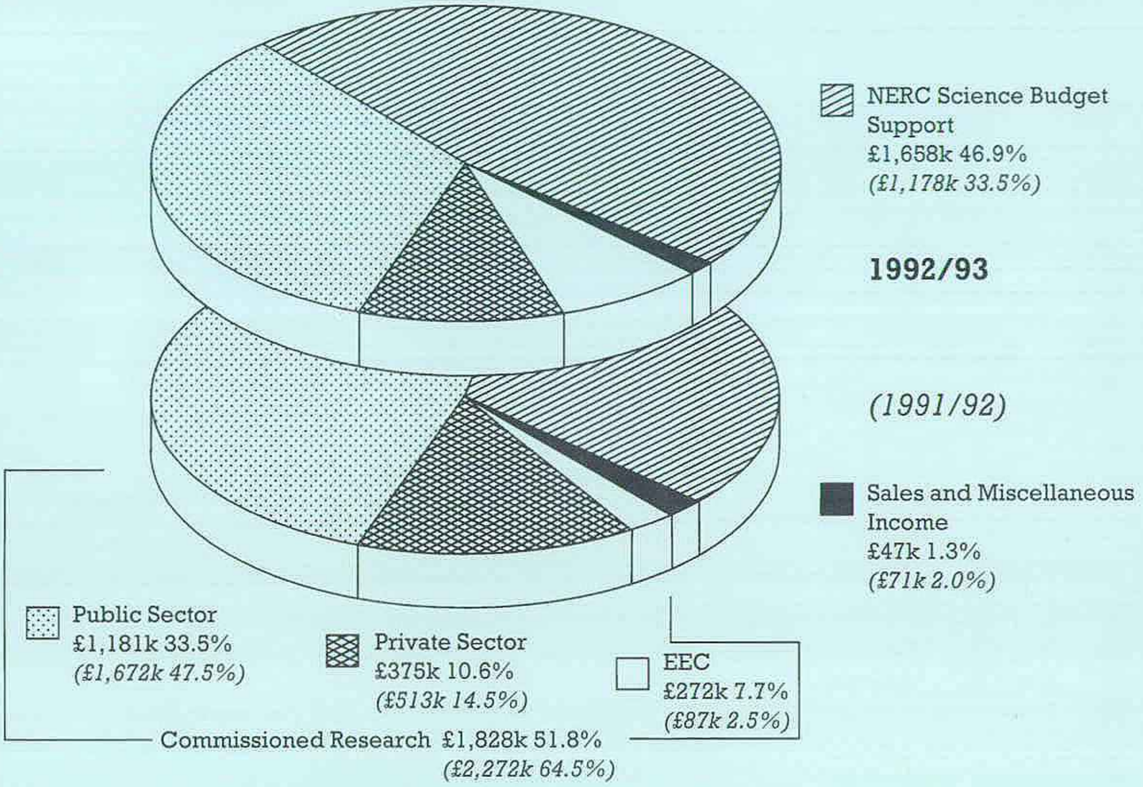
The Director
Professor J Gwynfryn Jones
Freshwater Biological Association
The Ferry House
Far Sawrey
Ambleside
Cumbria LA22 0LP
Telephone:
Windermere (STD Code 05394) 42468;
International (44 5394) 42468
Fax: (05394) 469144

Appendix 1
Finance and Administration

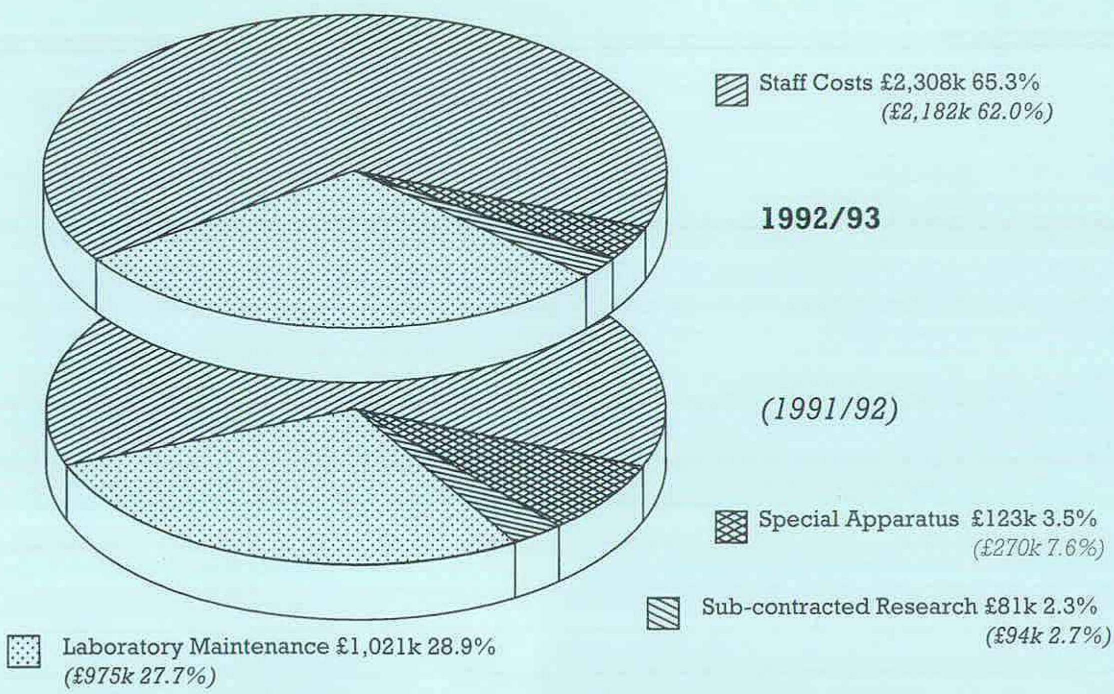
Finance

A summary of the financial accounts for the year ended 31 March 1993 is shown in the pie-charts below, together with the comparative figures for 1991/92.

INCOME



EXPENDITURE



IFE Management/Administration/Services

- **Prof J Gwynfryn Jones**
  Director (IFE & FBA)
  - **Prof A D Pickering**
    Head, Northern Division
    - **Mr C J Moakes**
      Finance
    - **Miss K M Atkinson**
      Management assistance
    - **Mrs M Thompson**
      Secretarial services
    - **Mr F R Ohnstad**
      Laboratory services
    - **Mr M A Rouen**
      Electronics
    - **Mr I Pettman**
      Library
  - **Prof A D Berrie**
    Head, Southern Division
    (to 31 January 1993)
    - **Mr D S Cordwell**
      Laboratory services
    - **Mrs D M Morton**
      Secretarial services

IFE Science Panel structure

- **Prof J Gwynfryn Jones**
  Director (IFE & FBA)
  - **Prof A D Pickering**
    Head, Northern Division
    - **Dr E W Tipping**
      Physico-chemical processes in catchments
    - **Dr J M Elliott**
      Fish population dynamics and management
    - **Dr B J Finlay**
      Microbes in the aquatic environment
    - **Dr A E Bailey-Watts**
      Assessment and prediction of changes in the aquatic environment
    - **Dr C S Reynolds**
      Management of lakes and reservoirs
  - **Prof A D Berrie**
    Head, Southern Division
    (to 31 January 1993)
    - **Dr M Ladle**
      River ecosystem processes
    - **Dr L C V Pinder**
      Ecology of large lowland rivers
    - **Dr J F Wright**
      Land-river interactions

Appendix 2
Staff list

Management/Administration

Director	Prof J G Jones	Grade 5
Head Northern Division	Prof A D Pickering	Grade 6
Head Southern Division (until 31 January 1993)	Prof A D Berrie	Grade 6
Management assistance	Miss K M Atkinson	HSO
Secretary to Director	Mrs M Thompson	EO
Secretarial services (Windermere)	Mrs V Muzalewski	PSec
	Mrs Y Dickens	Ty Pt
	Miss K Ross	Ty
	Mrs G Machin	SB1
(River Laboratory)	Mrs D M Morton	EO
	Mrs V B Palmer	AO Pt
Finance Officer	Mr C J Moakes	SEO
Finance and establishments	Miss P Parry	EO
	Miss S Taylor	AO

Management of lakes and reservoirs

Project Leader	Dr C S Reynolds	Grade 6
	Dr D G George	Grade 7
	Dr S C Maberly	SSO
	Dr L May	SSO
	Miss C Butterwick	HSO
	Mr I D M Gunn	HSO
	Ms D P Hewitt	HSO
	Dr A E Irish	HSO
	Mr A Kirika	HSO
	Mr A A Lyle	HSO
	Miss P S Davies*	RS
	Miss A Fulcher	RS

Assessment and prediction of changes in the aquatic environment

Project Leader	Dr A E Bailey-Watts	Grade 7
	Dr E Y Haworth	Grade 7
	Mrs M A Hurley	SSO Pt
	Mr G H M Jaworski	SSO
	Miss J E Corry	HSO
	Mrs J V Roscoe	SO Pt
	Miss C Bryant	RS
	Miss J A Taylor	RF

Ecology of large lowland rivers

Project Leader	Dr L C V Pinder	Grade 7
	Mr R H K Mann	Grade 7
	Dr A F H Marker	Grade 7
	Mr J A B Bass	SSO
	Mr D V Leach	SO
	Mr G D Collett**	SO
	Mr R A Garbutt	ASO
	Mr A C Pinder	ASO
	Mr P Garner*	RS

Land-river interactions

Project Leader	Dr J F Wright	Grade 7
	Dr P D Armitage	Grade 7
	Mr M T Furse	Grade 7
	Mr J H Blackburn	HSO
	Mr R J M Gunn	HSO
	Mr N J Grieve	SO
	Mrs J M Winder	SO
	Mrs K L Symes	ASO

Fish population dynamics and management

Project Leader	Dr J M Elliott	Grade 6
	Dr D T Crisp	Grade 7
	Dr T G Pottinger	SSO
	Dr I J Winfield	SSO
	Mr P R Cubby	HSO
	Mrs P A Tullett	HSO Pt
	Miss J M Fletcher	SO
	Miss E Baroudy	RS

Microbes in the aquatic environment

Project Leader	Dr B J Finlay	Grade 6
	Dr R W Pickup	Grade 7
	Mr K J Clarke	SSO
	Dr G H Hall	SSO
	Mr B M Simon	SSO
	Mrs R M Hindle	SO Pt
	Mrs H E H Mallinson	ASO
	Miss B Guhl	RS
	Miss K Lawlor	RS
	Dr G Esteban	RF
	Mr J Porter	RS
Culture Collection for Algae and Protozoa	Dr J G Day	SSO
	Miss S Brown	SO
	Miss M M Deville	SO
	Mrs J Tompkins	AO Pt
	Mrs A Cook	ASO Pt

Physico-chemical processes in catchments

Project Leader	Dr E W Tipping	Grade 6
	Dr P A Carling	Grade 7
	Dr P A Cranwell	Grade 7
	Dr J Hilton	Grade 7
	Mr T R Carrick	SSO
	Mr C P Woof	SSO
	Mr M S Glaister	HSO
	Mrs J P Lishman	HSO
	Mr E Rigg	HSO
	Mr L Nolan	SO
	Miss H G Orr	SO
	Mr J B James	ASO
	Mr N Hesketh	RS
	Mr A Kelsey	RS
	Mr J T Smith	RS

River ecosystem processes

Project Leader	Dr M Ladle Temp	Grade 6
	Mr H Casey	Grade 7
	Mr R T Clarke	Grade 7
	Dr F H Dawson	Grade 7
	Dr W A House	Grade 7
	Dr J S Welton	Grade 7
	Mr I S Farr	SSO
	Mr W R C Beaumont	HSO
	Mr P Henville	HSO
	Mrs S M Smith	HSO
	Mr D R Orr	SO
	Mr A T Ibbotson*	RS

Laboratory services

Windermere Laboratory	Mr F R Ohnstad	SPTO
	Mr M A Rouen	SSO
	Mr P V Allen	HSO
	Mr T I Furnass	GO
	Mr B M Godfrey	PTO
	Mr D I Aspinall	PTO
	Mr J Crompton	PTO
	Mr P M Hodgson	PTO
	Mr G Gregson	Ind
	Mrs J Gregson	Ind
	Miss R J Bainbridge	Ind
Library	Mr I Pettman	SLib
	Mr I D McCulloch	ALib
	Miss C M Williams	$ALib
	Mrs K Crompton	AO
	Mrs K J Pearson	AO Pt
	Mrs O Jolly	AO Pt

Fritsch Collection of Algal Illustrations

Honorary Curator	Dr J W G Lund*	
	Mrs E G Devlin*	
	Mrs E Monaghan*	
River Laboratory	Mr D S Cordwell	PTO
	Mr B E Dear	SO
	Mr S C Shinn	PGSE
	Mr G A Richards	Ind
	Mrs J Whitmarsh	Ind

Abbreviations:

ALib	Assistant Librarian
AO	Administrative Officer
ASO	Assistant Scientific Officer
EO	Executive Officer
GO	Graphics Officer
HPTO	Higher Professional & Technical Officer
HSO	Higher Scientific Officer
Ind	Industrial
PGSE	Process & General Supervisory E
PSec	Personal Secretary
Pt	Part-time
PTO	Professional & Technical Officer
RF	Research Fellow
RS	Research Student
SB1	Support Band 1
SEO	Senior Executive Officer
SLib	Senior Librarian
SO	Scientific Officer
SPTO	Senior Professional & Technical Officer
SSO	Senior Scientific Officer
Ty	Typist
*	FBA not IFE establishment
**	unpaid leave

Appendix 3
Project list

Management of lakes and reservoirs

Project	T04050-5 at Windermere and Edinburgh Laboratories
Programme	TFS4 Management of aquatic ecosystems
Leader	C S Reynolds
Funding	Science budget/commission/miscellaneous consultancies
Objectives	To obtain greater resolution and experience in all biological aspects of stored-water quality, including methodology development, tracing physical water movements, chemical recycles and pelagic population dynamics. To develop computational methods for predicting and applying state-of-the-art knowledge to practical problems.

Ecology of large lowland rivers

Project	T04052-5 at Eastern Rivers and Windermere Laboratories
Programme	TFS4 Management of aquatic ecosystems
Leader	L C V Pinder
Funding	Science budget/commission
Objectives	The broad objectives are to quantify the physical, chemical and biological interactions within large lowland river systems and to develop models that describe these interactions and are capable of predicting the effects of changes in factors such as management and levels of pollution. Immediate, specific objectives include:- a) Development of a model of flow relating hydrological and morphological properties of channels in order to predict sedimentation and transport of particulates, dissolved pollutants and dynamics of phytoplankton. b) Determination of seasonal and spatial patterns of abundance of invertebrates and larval and juvenile cyprinid fish in the Great Ouse and relating these to factors such as channel morphology, vegetation, water velocity, management, recreational pressures and pesticides. c) Examination of the effects of changes in light climate, due to turbidity, on the growth and development of macrophytes and phytoplankton in the Great Ouse.

Land-river interactions

Project	T04053-5 at River and Windermere Laboratories and ITE
Programme	TFS4 Management of aquatic ecosystems
Leader	J F Wright
Funding	Science budget/commission
Objectives	This project, which is heavily commissioned, includes strategic and applied research in river management, conservation, the impact of land-use on river biota and environmental impact assessment. The relationship between catchment features/land use and the river biota is being addressed through collaborative work with the Institute of Terrestrial Ecology (ITE) and also through a commission on headwater streams. Current objectives include i) research on river management and pollution assessment which is responsive to the requirements of the National Rivers Authority; ii) studies to provide the statutory nature conservation organisations in Great Britain, with information on river biota and techniques for site appraisal; iii) provision of a freshwater component to the 1990 Countryside Survey; iv) examination of the behaviour of pesticides in running waters and the impact of these and other pollutants on the fauna; v) studies on the response of the fauna and flora to reduced flows and habitat loss in a river; vi) development of a database on the biota and environmental conditions in British rivers to service various sub-projects and ensure the availability of the data for future uses (e.g. environmental impact assessments, long-term monitoring, climate change studies).

Microbes in the aquatic environment

Project	T10062-5 at Windermere Laboratory
Programme	TFS10 Environmental microbiology
Leader	B J Finlay
Funding	Science budget/commission
Objectives	a) To investigate the identity, diversity, distribution and functional role of microbes and microbial processes in aquatic (especially freshwater) environments. b) The innovative exploitation of aquatic microbes with biotechnological potential, especially algae, protozoa and free-living prokaryotes.

Fish population dynamics and management

Project T11050-5 at Windermere, River and Teesdale Laboratories
Programme TFS11 Freshwater biology and chemistry
Leader J M Elliott
Funding Science budget/commission
Objectives
a) To obtain quantitative information on variations in numbers, biomass, growth rates, mortality rates, production rates, movements and feeding of fish and their food organisms in streams, rivers, lakes and reservoirs. To identify the extrinsic and intrinsic factors affecting these variables and to develop mathematical models that can be used to predict quantitative changes in these variables. Particular emphasis is placed on populations of brown trout, pike, perch, charr and the rare coregonids (schelly, vendace).
b) To elucidate the basic physiological and endocrinological changes that occur when fish are subjected to acute and chronic environmental stress, with special emphasis on survival, disease resistance, growth and reproduction. To investigate methods for controlling the stress response by modifying the fish's environment or by selecting, for breeding purposes, fish with low sensitivities to environmental stress.
c) To interpret and apply the results of the above work so that they can be used for the scientific management and conservation of stocks of freshwater fish and their environments, especially in relation to human perturbations such as eutrophication, acidification, changes in land use and changes in climate.

Physico-chemical processes in catchments

Project T11052-5 at Windermere and River Laboratories
Programme TFS11 Freshwater biology and chemistry
Leader E W Tipping
Funding Science budget/commission
Objectives
a) To investigate the pathways and transformations of particulate and soluble chemical components in catchments.
b) To improve understanding of the fundamental physical, chemical and biological processes operating in soil waters, rivers and lakes.
c) To develop quantitative models of individual and combined processes.

River ecosystem processes

Project T11053-5 at River and Windermere Laboratories
Programme TFS11 Freshwater biology and chemistry
Leader M Ladle
Funding Science budget/commission
Objectives This project includes strategic and applied research into river ecosystem processes. The study area ranges from procedures designed to measure the kinetics of chemical transport processes at the particle/water interface; through physical, chemical and biological investigations designed to improve management and understanding of plant communities in running waters; studies of the environmental impact of management activities including control measures for insect pests such as the Blandford Fly; development of techniques for the determination of runs of migratory salmonid fishes and for the validation of fish counting installations; establishment of the natural patterns of recruitment and resource utilisation by coarse fishes and the solution of problems of classification, identity, distribution and population genetics in a wide range of aquatic organisms.

Assessment and prediction of changes in the aquatic environment

Project T11055-5 at Windermere, Edinburgh and River Laboratories
Programme TFS11 Freshwater biology and chemistry
Leaders A E Bailey-Watts
Funding Science budget/commission
Objectives
a) The acquisition of physical, chemical and biological data from diverse aquatic ecosystems with the primary purpose of identifying and quantifying environmental changes associated with man's activities, distinguishing man-made change from natural variations and trends and giving early warning of undesirable effects.
b) To seek a better understanding of organisms and fundamental processes within the aquatic environment and to identify particular variables, processes and aquatic environments which are sensitive to change.
c) To develop qualitative and quantitative models for the assessment and prediction of change in aquatic ecosystems as influenced by catchment perturbation.
d) To apply the knowledge to the mitigation and preferably prevention of problems attributed to cultural eutrophication, acidification and other results of human pressures.

Appendix 4
Publications

Scientific Papers

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Addresses

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Institute of Freshwater Ecology
Windermere Laboratory
Far Sawrey
Ambleside
Cumbria LA22 0LP

Telephone: 05394-42468
Telex: 94070416 WIND G
Facsimile: 05394-46914

Contact: Prof A D Pickering

Institute of Freshwater Ecology
River Laboratory
East Stoke
Wareham
Dorset BH20 6BB

Telephone: 0929-462314
Telex: 94070672 WARE G
Facsimile: 0929-462180

Contact: Dr J Hilton

Institute of Freshwater Ecology
Teesdale Laboratory
c/o Northumbrian Water
Lartington Treatment Works
Lartington
Barnard Castle
Co Durham DL12 9DW

Telephone: 0833-50600
Facsimile: 0833-50827

Contact: Dr D T Crisp

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Eastern Rivers Laboratory
Monks Wood Experimental Station
Abbots Ripton
Huntingdon
Cambridgeshire PE17 2LS

Telephone: 04873-381
Telex: 32416 MONITE G
Facsimile: 04873-467

Contact: Dr L C V Pinder

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Correspondence should be addressed:

Freshwater Biological Association
The Ferry House
Far Sawrey
Ambleside
Cumbria LA22 0LP

Telephone: 05394-42468
Telex: 94070416 WIND G
Facsimile: 05394-46914

Contact: Prof J Gwynfryn Jones

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Windermere Laboratory
Far Sawrey
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United Kingdom

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